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THE UNIVERSITY OF ALBERTA

PREDICTION OF SATURATED HYDRAULIC CONDUCTIVITY IN PEAT

by

RICHARD DALE SHERSTABETOFF

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE

IN

FOREST SOILS

DEPARTMENT OF SOIL SCIENCE

EDMONTON, ALBERTA

SPRING, 1988

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled PREDICTION OF SATURATED HYDRAULIC CONDUCTIVITY IN PEAT submitted by RICHARD DALE SHERSTABETOFF in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE in FOREST SOILS.

Donald J. Pluth

Supervisor

Larry W. Swanlund

Robert T. Hardin

Date April 27, 1988

Dedication

This thesis is dedicated to my parents; who brought me into this world, raised me and continually supported my endeavours. Their unceasing devotion to our family has engraved values that will never be forgotten. I thank them deeply from the bottom of my heart.

Abstract

In-situ utilization of peatlands for agriculture, forestry, horticulture or fuel may entail lowering the watertable. As an input required in drainage design, an accurate estimate of in-situ hydraulic conductivity (K) can be difficult to obtain for peat. This study identifies variables in peat that relate to K and uses these variables to predict K in peat within a one km^2 area of a fen peatland complex located in central Alberta.

During previous drainage design investigations, K by the falling head piezometer method was measured on a grid with 200 m spacing at 1, 2 and 3 m depths. Peat properties were determined on duplicate samples removed from close proximity to the piezometer cavity.

Variables describing the peat's fiber size distribution, degree of decomposition, and the location of the peat volume within the catotelm relate best to K. The highest, most significant correlations ($P < 0.01$) with K were with unrubbed fiber ($r=0.40$), total nitrogen ($r=-0.33$) and the elevation (or depth) of the piezometer cavity ($r=0.33$).

Four groups of variables identified through principal components analysis (PCA) account for 74% of the variation within the data. These groups were interpreted as representing degree of decomposition, the decrease in K with depth, the variation in in-situ moisture with fiber content and the dominant botanical (herbaceous) constituent in the peat. Based on variable loadings from PCA, 11 variables were selected for regression analysis.

Fifty-eight percent of the variation in K ($P < 0.001$) is explained by the equation,

$$\log_{10}K = -10.3 + 0.3E + 0.06URF^{0.5} - 0.04\sin^{-1}(FL/100)^{0.5} + 0.2W^{0.5} + 263.6CEC^{-1} - 0.02RF$$

where E is the elevation (m) above an arbitrary datum of the K measurement within the peatland, URF is the unrubbed fiber content (%), FL and W are the forest litter (%) and wood (%) contents, CEC is the cation exchange capacity (cmol (1/2 Ba++)kg^{-1}) and RF is the rubbed fiber content (%) of the peat. The largest proportion of variation was explained by elevation (20%) and unrubbed fiber content (17%). The remaining explained variation (21%) was split almost equally among forest litter (4%), wood (7%), CEC (5%) and rubbed fiber content (5%). Residual analysis revealed the model underestimated observed values of K between 10^{-5} and 10^{-6} $m\ s^{-1}$. Accuracy and reliability of the model was not assessed.

Acknowledgements

First and foremost, I would like to thank my best friend, Cindy Lewis, for her constant support during preparation of this manuscript. Her patience, understanding and advice will always be remembered.

Sincere appreciation is extended to my supervisor, Dr. D. Pluth, whose guidance was always welcomed. I would also like to thank the other members of my examination committee, Dr. L. Turchenek, Dr. J. Toth, and Dr. R. Hardin for reviewing the manuscript and offering criticism.

Special thanks is extended to Dr. J. Toth and Don Gillard for conducting the in-situ hydraulic conductivity measurements and making the data available to me. Deborah Storr, Alex Schwarzer, Joe Beres, Wayne McKean, Dr. Dale Vitt, Helen Kubiw and Barb Nicholson are acknowledged for their help in the lab. I would like to thank Tracy Matheson for her able assistance in typing the manuscript.

Finally, to my brother and friends-on and off campus - I would like to thank them for their stimulating discussions that put this project into its proper perspective.

Table of Contents

Chapter	Page No.
1.0 Introduction	1
2.0 Literature Review	3
2.1 Theoretical Considerations	3
2.2 Measurement of Hydraulic Conductivity	10
2.3 Hydraulic Conductivity of Peat	19
2.4 Modelling Water Transmission in Peat	22
2.5 Summary	28
3.0 Materials and Methods	30
3.1 Study Area	30
3.2 Field Procedures	32
3.2.1 Sampling and Implications on Statistical Analyses	32
3.2.2 In-situ Determination of Hydraulic Conductivity	36
3.2.3 Description and Classification of Soil Profiles	38
3.3 Laboratory Analyses	38
3.3.1 Physical Analyses	39
3.3.2 Chemical Analyses	40
3.3.3 Botanical Analysis	41
3.4 Data Analyses	44
3.4.1 Assessment of Sample Distributions	44
3.4.2 Data Transformations	45

Page No.

3.4.3 Statistical Analyses 49

3.4.3.1 Analysis of Variance 49

3.4.3.2 Pearson Product Correlations 51

3.4.3.3 Principal Components Analysis 51

3.4.3.4 Regression Analysis 53

3.4.3.5 Trend Surface Analysis 55

4.0 Results and Discussion 57

4.1 Peat Characteristics 57

4.2 Prediction of Hydraulic Conductivity 62

4.2.1 Assessment of Variable Interdependence 62

4.2.1.1 Correlations 62

4.2.1.2 Principal Components Analysis 67

4.2.2 Regression Analysis 72

4.2.3 Residual Analysis 83

5.0 Conclusions 91

6.0 References 93

7.0 Appendices 102

7.1 Soil Profile Descriptions and Classifications 102

7.2 Data 121

List of Tables

Table		Page No.
2.1	Summary of in-situ values of hydraulic conductivity for peat	20
2.2	Summary of values of horizontal and vertical hydraulic conductivity for peat	21
2.3	Values of hydraulic conductivity for different kinds of peat in the catotelm of undrained mires	23
3.1	Surface water chemistry within the study site (n = 30)	33
3.2	Mean values (standard errors) for parameters associated with the botanical analysis of peat (n = 112)	43
3.3	Lambda values and corresponding power transformations	47
3.4	Calculated lambda values and data transformations employed	48
3.5	Depth class intervals and widths	50
4.1	Mean values (coefficients of variation) for selected properties	60
4.2	F values from one-way analysis of variance and polynomial contrasts by depth class	61
4.3	Simple product correlations of selected properties with K (n = 56)	63
4.4	First order partial correlations ($P < 0.10$) between elevation and K, controlling for selected peat properties (n = 56)	64
4.5	Simple correlations of selected peat properties (n = 56)	66
4.6	Principle components analysis: distribution of variance and variable loadings for retained components	68
4.7	Prediction of K at 1, 2 and 3 m depths: comparison predicted and observed values	84

List of Figures

Figure		Page No.
2.1	Diagram of a constant-head system for measurement of hydraulic conductivity	12
2.2	Diagram of a falling-head system for measurement of hydraulic conductivity	13
2.3	Geometry of an auger-hole test	15
2.4	Geometry of a piezometer test	17
3.1	Sampling locations	34
3.2	Composite sampling in the vicinity of the piezometer cavities	37
4.1	Peat thickness (m) across the study site	58
4.2	Soil subgroups occurring within the study site	59
4.3	Boxplots of unrubbed fiber and volumetric moisture content with depth	71
4.4	Percent fit explained by variables in the model	74
4.5	Linear change in unrubbed fiber content at 1 m depth across the study site	76
4.6	Linear change in wood content at 2 m depth across the study site	77
4.7	Linear change in forest litter content at 2 m depth across the study site	78
4.8	Linear change in forest litter content at 1 m depth across the study site	80
4.9	Linear change in cation exchange capacity at 1 m depth across the study site	81
4.10	Linear change in cation exchange capacity at 2 m depth across the study site	82
4.11	Prediction of K at 1, 2 and 3 m depths: histogram and normal probability plot of standardized residual values	85
4.12	Prediction of K at 1, 2 and 3 m depths: scatterplot of standardized predicted and residual values	86
4.13	Prediction of K at 1, 2 and 3 m depths: standardized partial regression plots of elevation and unrubbed fiber content with K	88
4.14	Prediction of K at 1, 2 and 3 m depths: standardized partial regression plots of cation exchange capacity (CEC) and rubbed fiber content with K	89
4.15	Prediction of K at 1, 2 and 3 m depths: standardized partial regression plots of wood and forest litter contents with K	90

List of Plates

Plate		Page No.
3.1	Aerial photograph (1:40,000, 1987) of the study site. Study site outlined; photograph after drainage.	31

1.0 Introduction

Peatlands (mires) cover extensive areas in the world-in Canada and in the U.S., 112 and 21 million hectares, respectively (Lucas 1982). In Alberta alone, there are 12 million hectares representing 20% of the land base (Tarnocai 1984). In-situ utilization of mires - whether for agriculture, forestry, horticulture or fuel - may entail lowering the watertable. For efficient drainage, a representative estimate of hydraulic conductivity (K) of the organic material is required.

Saturated hydraulic conductivity can be determined in the laboratory under conditions of constant or falling head or in the field (in-situ). Two of the most common techniques for in-situ determination of K are the auger-hole and seepage tube or piezometer methods. These methods are tedious, time-consuming and beset by theoretical and practical problems.

Several researchers (Rycroft et al 1975b, Hemond and Goldman 1985) have observed the variation of K over time and with hydraulic head during in-situ measurements. Possible explanations center on certain physio-chemical properties of peat and their influence on boundary conditions prior to and during the test. From a practical standpoint, maintaining the dimensions of an unlined cavity in such an unstable soil such as peat becomes a problem. Because of the structural diversity in peat, the actual value obtained from the measurement may or may not be representative of spatial or vertical change in the mire.

Previous research has shown that K is related to various attributes of the peat. Reasonably good linear and nonlinear correlations with K have been reported for botanical composition, degree of decomposition,

bulk density, fiber content, substance volume (porosity), storativity, and surface loading. However, there have been few documented attempts to integrate and rank these attributes with respect to their importance in predicting K in peat. Consequently, the objectives of this study are to:

1. identify and rank various attributes of peat with respect to their relationship with K; and,
2. use these to develop an empirical (regression) model capable of predicting K within the study site.

2.0 Literature Review

The purpose of this literature review is to present the concept of hydraulic conductivity, discuss methods of measuring it and review various approaches to evaluating it in peat.

2.1 Theoretical Considerations

Flow through porous media can be viewed microscopically or macroscopically (Scheidegger 1974, Domenico 1972). At the microscopic level, the flow medium is considered a continuum where fluid motion can be described geometrically if the position of every fluid particle is known at every time-instant. Macroscopic examination of flow deals with bulk description of flow components made on a control volume larger than individual pores yet small enough to preclude significant variation. DeWiest (1969) and Scheidegger (1974) provide a more complete review of microscopic flow while Hubbert (1956) addresses the application of microscopic flow to macroscopic phenomena.

Macroscopic quantification of flow through uniform porous media was first documented in 1856 by a French engineer, Henri Darcy, investigating seepage rates through sand filters in the city of Dion, France (Darcy 1856 cited by Scheidegger 1974). He established that specific discharge (q) was directly proportional to the drop in hydraulic head (ΔH) down the column and indirectly proportional to column length (L),

$$q = -K(\Delta H/L)$$

or, in differential form,

$$q = -K\partial h/\partial l$$

Specific discharge (flux) has dimensions LT^{-1}; hydraulic gradient ($\Delta H/L$) is dimensionless; and, the proportionality constant (hydraulic conductivity), K, has dimensions of velocity, LT^{-1}.

Hydraulic conductivity depends on both medium and fluid attributes - in short, the medium's intrinsic permeability and the fluid's viscosity. Intrinsic permeability reflects only those qualities of the medium that influence flow; that is, the medium's total porosity, pore size distribution and tortuosity. Collectively, these attributes define pore geometry. Fluid viscosity indicates a fluid's resistance to flow or its internal friction during flow and varies with temperature, type and concentration of solutes. Hopmans and Dane (1986) indicate that the effect of temperature on K parallels changes in K arising from changes in fluid viscosity. Given temperature fluctuations that may occur in shallow groundwater flow systems (5-10°C), fluid viscosity can be expected to vary by 15% assuming negligible change in solute type and concentration.

Hydraulic conductivity may not be uniform within a medium and/or, at a given point within the medium, may vary with the direction of measurement. If K is independent of position within a medium, the medium is termed homogenous; otherwise, heterogeneity exists. Freeze and Cherry (1979) identify three broad classes of heterogeneity: layered heterogeneity, common in sedimentary rocks, lacustrine and marine deposits; discontinuous heterogeneity, attributed to stratigraphic discontinuities such as faults; and, trending heterogeneity, possible in

any formation type but most common in deltas, alluvial fans and glacial outwash plains.

If at a given point within the medium, the magnitude of K varies depending on the direction it is measured, the medium is termed anisotropic at that point (vs. isotropic). Principal directions of anisotropy correspond to directions in space where minimum and maximum values of K occur perpendicular to each other. From Boelter (1965) and Rycroft et al (1975a) the ratio between horizontal and vertical anisotropy for K in peat ranges between 0.2:1 and 4:1. Regardless of peat type, it appears that as decomposition progresses, this ratio approaches unity.

Recognizing that most soils have some degree of anisotropy, the general form of Darcy's law presented earlier can be expressed as,

$$q_x = -K_x \partial h/\partial l$$

Bear (1972) identified nine components of K for flow in three dimensions and expressed these in matrix form. For most flow regions coordinate systems can be arranged such that the principal directions of anisotropy correspond to x, y and z coordinate axes and, consequently, only three flow vectors are used.

Mathematical description of flow - whether in homogenous, isotropic or heterogenous, anisotropic media-requires integration of Darcy's law with the (continuity) equation describing the conservation of fluid mass during flow. For saturated media, two flow conditions exist: steady-state and nonsteady or transient flow. For both flow conditions, accurate specification of boundary values are required.

Under steady-state flow, the magnitude and direction of flow velocity remains constant with time. Using the equation of continuity and Darcy's law, steady-state flow through an anisotropic saturated porous medium can be described by,

$$\frac{\partial}{\partial x}(K_x\frac{\partial h}{\partial x}) + \frac{\partial}{\partial y}(K_y\frac{\partial h}{\partial y}) + \frac{\partial}{\partial z}(K_z\frac{\partial h}{\partial z}) = 0$$

If the medium is isotropic and homogenous, K terms can be removed - that is, $K_x = K_y = K_z$ and K is equal at all points - leaving Laplace's equation,

$$\frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial y^2} + \frac{\partial^2 h}{\partial z^2} = 0$$

To obtain solutions for these equations, the flow region must be defined, conditions at the boundaries must be specified, hydrogeological parameters influencing flow must be known and there must be a (mathematical) method of solution (Freeze and Cherry 1979).

Under transient or nonsteady flow, the magnitude and direction of flow velocity changes with time owing to a change in fluid storage within the porous medium. Transient flow through an anisotropic saturated porous medium can be described by,

$$\frac{\partial}{\partial x}(K_x\frac{\partial h}{\partial x}) + \frac{\partial}{\partial y}(K_y\frac{\partial h}{\partial y}) + \frac{\partial}{\partial z}(K_z\frac{\partial h}{\partial z}) = S_s\frac{\partial h}{\partial t}$$

where S_s is specific storage (Freeze and Cherry 1979). Similar to steady-state flow in an isotropic, homogenous medium, transient flow through an isotropic, homogenous medium can be described by,

$$\frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial y^2} + \frac{\partial^2 h}{\partial z^2} = \frac{S_s}{K}\frac{\partial h}{\partial t}$$

To obtain solutions for these equations, the same information is required as that mentioned for steady-state flow but for transient flow, the initial conditions within the flow region must also be specified.

Valid application of Darcy's law and the associated proportionality constant, K, depends on several correct assumptions concerning the condition of flow. Swartzendruber (1962) and Hubbert (1956) have

indicated lower and upper limits of Darcy's law. In certain fine-grained sediments of low conductivity, evidence indicates that flow may only occur after a threshold hydraulic gradient has been exceeded. At high flow velocities through larger pores, laminar flow may be supplanted by turbulent flow and the relationship between hydraulic gradient and specific discharge becomes nonlinear. The onset of turbulent flow can be identified with the aid of the Reynold's number (Re), defined as,

$$R_e = \rho q d/\mu$$

where ρ and μ are fluid density and viscosity, q the specific discharge and d the mean pore diameter. Bear (1972) indicates that for Reynold's numbers between 1 and 10 laminar flow prevails and use of Darcy's law is valid.

Some additional assumptions associated with Darcian flow are that chemical and biological phenomena do not alter fluid or medium properties and that isothermal conditions exist. Frankenberger et al (1979) found that in submerged soils, K decreased slowly over time and attributed this to soil bacteria. Proposed mechanisms for this decrease in K are associated with the production and entrapment of gas, the accumulation of bacterial metabolites in soil pores and the microbial destruction of soil structure. In such a medium as peat, biological activity associated with decomposition could have a significant effect on K.

Differences in temperature within a flow region can cause flow even when hydraulic gradients do not exist (Gurr et al 1952). Coupling of flow can occur not only with temperature gradients but also with

electrical and chemical gradients. Although temperature gradients can initiate flow, the primary and most significant driving force is assumed to be the hydraulic gradient.

In the majority of hydrological studies it is often assumed that application of Darcy's law is valid. However, several instances have been documented indicating the existence of flow in porous media (Scheidegger 1974) or, more specifically, in peat (Ingram 1983) that does not follow Darcy's law. Non-linear flux-gradient relationships have been observed in both laboratory and field measurements. In lab permeameter studies, Galvin and Hanrahan (1967), Rycroft (1971) and Waine (1976) noted that with increasing hydraulic gradients, a non-linear rise in flux occurred. Similar occurrences were documented in field tests using seepage tubes by Dai and Sparling (1973), Ingram et al (1974) and Rycroft et al (1975b).

Confusing terminology or misuse of terms in the literature makes it difficult to understand possible explanations for these observed non-linear flux-gradient relationships. In certain instances (Ingram 1983), reference to non-Darcian flow deals with misspecification of boundary values during the K measurement; that is, where steady-state conditions are assumed to exist when, in fact, there is a change in storage and transient conditions occur. Other instances (Rycroft et al 1975a) correctly refer to non-Darcian flow as it occurs in highly humified peats where interactions between soil water and the porous medium cause these nonlinear flux-gradient relationships. A brief discussion clarifying this point follows.

Since peat has significant elastic storativity, water storage or

potential within subsurface layers depends on local variations in hydrostatic pressure (Ingram 1983). Applied to seepage tube or auger-hole methods of measuring K, the hydraulic gradient imposed at the initiation of the test causes changes in storage in peat within the vicinity of the unlined cavity. Although Rycroft et al (1975b) proposed two mechanisms, the authors felt that compression of the peat mass and coincident changes in porosity near the unlined cavity most likely caused a greater influx of water into the cavity at the onset of the test (depletion mode). As the test progressed, values of K decreased. Because of this phenomenon, seepage tube measurements should continue for at least 10^3 minutes so flux arising from changes in storage becomes negligible and a constant value of K is obtained.

Instances of non-Darcian flow in humified peats also relate to the interaction between soil water and the matrix and the effect of decomposition on this interaction. In more humified peats, it has been suggested by Volarovich and Churaev (1966, 1968) that a degree of "structuring" of water occurs in small pores in the vicinity of colloids. This results in the fluid having shear rigidity which is more characteristic of a Bingham liquid (Hillel 1980) versus a Newtonian liquid. As decomposition progresses, gaseous by-products accumulate in pores that become progressively smaller. In a capillary tube containing both liquid and gas, a large difference in pressure may be required to initiate flow (Scheidegger 1974). With respect to peat, Bodarenko et al (1975) suggested that pore blockage by gaseous decomposition products caused non-linear flux-gradient relationships. However, these effects were not indicated by Rycroft (1971) or Waine (1976).

To reiterate, it seems evident that the linear flux-gradient relationship described by Darcy's law occurs in peats that are, at most, moderately humified. In highly decomposed peats, inappropriate specification of boundary conditions for methods used to measure K, interactions between soil water and the collidal peat fraction and the effect of decomposition on the peat matrix interfere with accurate estimation of K. Consequently, highly-humified peats can be added to the list of other porous media reported to exhibit non-Darcian flow; for instance, fine-grained sediments (Mitchell and Younger 1967) and swelling soils (Russell and Swartzendruber 1971). Keeping in mind the theoretical considerations associated with measuring K in peat, a brief discussion of methods used to estimate K follows.

2.2 Measurement of Hydraulic Conductivity

Hydraulic conductivity can be measured in the field (in-situ) or in the lab using a relatively undisturbed sample. Field determinations are more representative since the moisture profile of the peat remains largely unaffected and the larger effective sample size tends to alleviate the impact of local changes in composition on the result obtained. Obtaining cores for laboratory determinations results in sample disturbance that leads to structural alterations or changes in porosity. Consequently, emphasis will be placed on field methods and their associated values of K.

Once a representative and relatively undisturbed core has been obtained from the field, K can be measured in the lab under conditions of either constant or falling head (Klute 1965). For measurement using a

constant head (Fig. 2.1), the core is placed within a cylinder of known dimensions, a constant head is maintained and the quantity of flow (Q) is measured over time (t). Hydraulic conductivity is calculated using the formula,

$$K = QL/At\Delta H$$

where A is the cross sectional area of flow. For measurement under conditions of falling head, the core is placed in an apparatus similar to the one illustrated in Fig. 2.2 and the change in hydraulic head (ΔH) over time is recorded. Hydraulic conductivity is calculated using the formula,

$$K = (aL/At)\ln(H_1/H_2)$$

where a is the cross sectional area of the standpipe, L is the length of the sample and A is the cross sectional area of flow. It is recommended that the constant head system is most suited for samples with K greater than 1.6×10^{-6} m s^{-1}. Care should be taken that preferential flow does not occur along the walls of the flow chamber, that the concentration and chemical nature of the percolating fluid is similar to in-situ soil water (Reeve 1957), and that isothermal conditions prevail along the length of flow.

Methods for measuring K in the field can be made either above or below the watertable. Techniques proposed for measuring K above the watertable are the double-tube method (Bouwer 1961, 1962), the shallow-well pump method and the field permeameter method (Winger 1960). Discussion of these methods is beyond the scope of this review and the reader is referred to Boersma (1965) for further details.

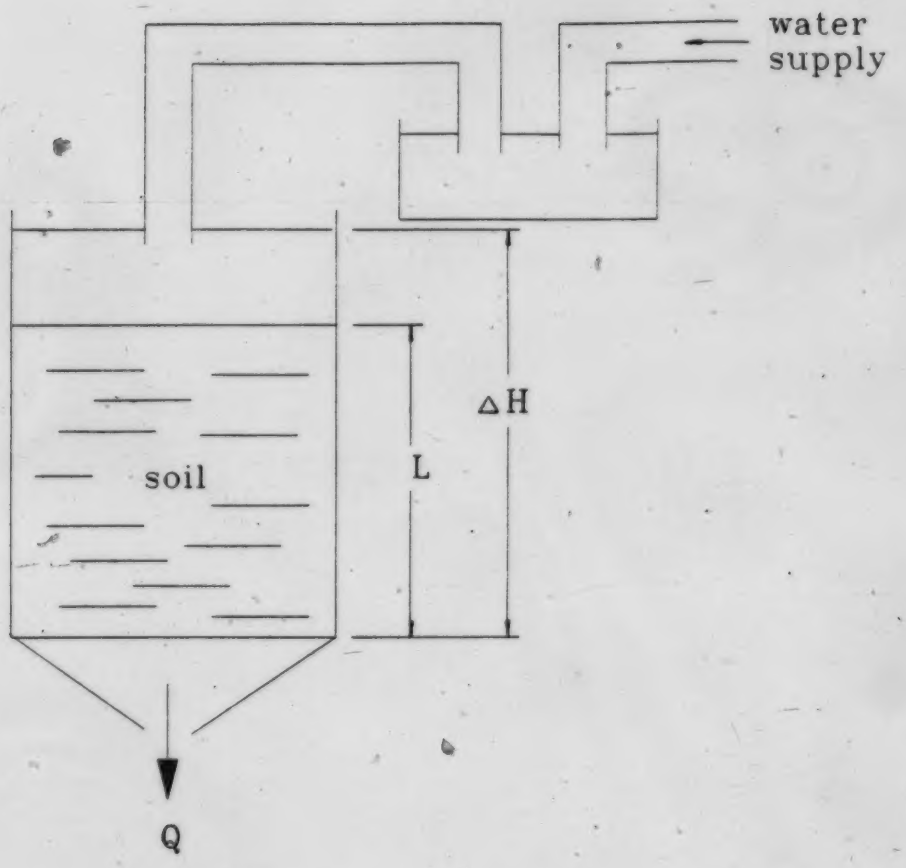


Figure 2.1 Diagram of a constant-head system for measurement of hydraulic conductivity

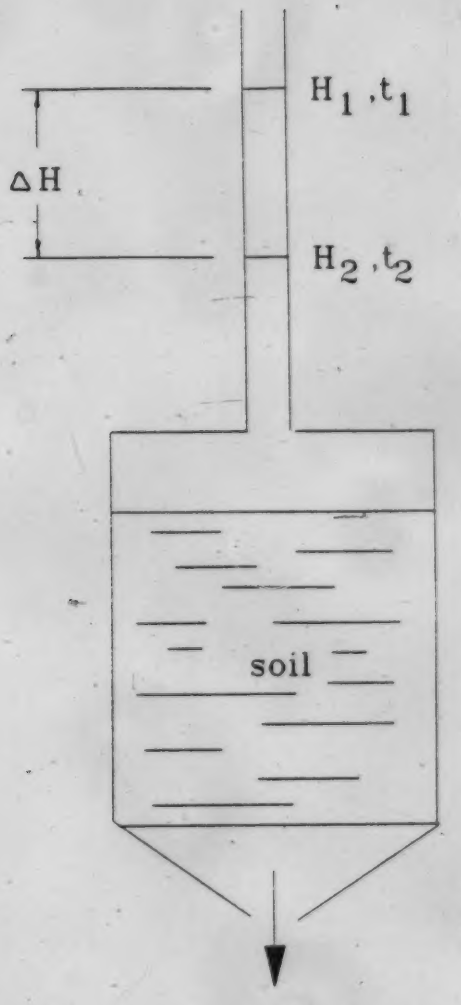


Figure 2.2 Diagram of a falling-head system for measurement of hydraulic conductivity

Below the watertable, K is commonly measured using either the auger-hole method or the piezometer/seepage tube method (Hvorslev 1951, Cedergren 1967). With the auger-hole method, an unlined cavity is constructed below the watertable with a minimum of disturbance (Fig. 2.3). It is allowed to fill with water and bailed several times to eliminate the effect of sealing on the walls of the cavity that may have occurred during construction. The equilibrium water level is recorded in the cavity, a hydraulic gradient is imposed by either removing (depletion) or adding (recharge) water and its recovery is measured over time. Hydraulic conductivity ($m\ s^{-1}$) is calculated using the formula,

$$K = (R/16DS)(h_2-h_1/t_2-t_1) \qquad \text{for } D/R<50$$

where,

D	-	length (m) of the unlined cavity below the watertable
R	-	hole radius (m)
S	-	shape factor coefficient
t_2-t_1	-	time increment (s)
h_2-h_1	-	hydraulic head increment (m).

The value obtained for K using the auger-hole method represents an average since soil characteristics change with depth with the result dominated by more permeable layers. Maasland and Haskev (1957) indicated that the most accurate result is obtained if the amount of return flow in the cavity is limited to 20% of the amount of water removed from the hole. In addition, they found auger-hole measurements were reproducible to within 10%.

For measuring the K of individual layers, Hvorslev's (1951)

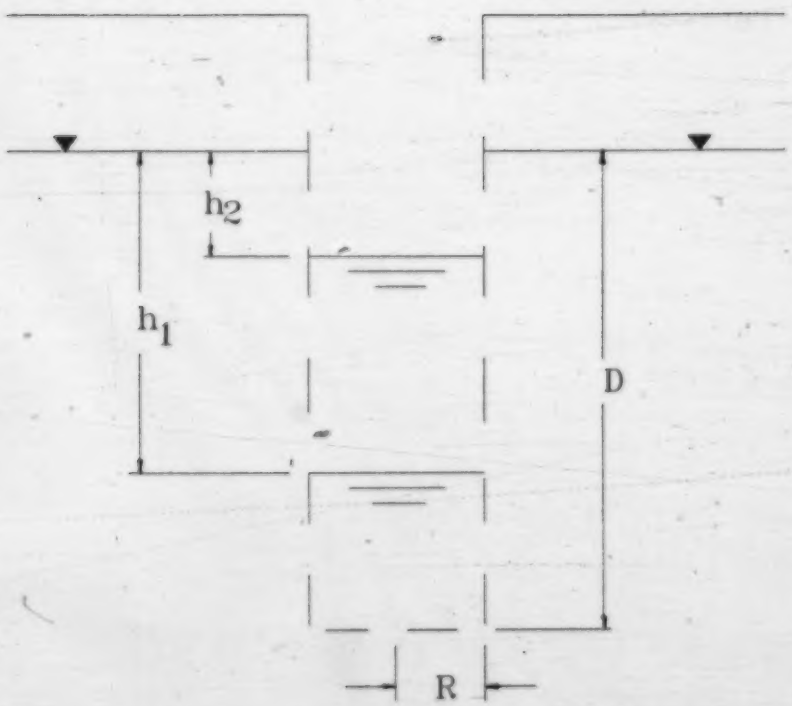


Figure 2.3 Geometry of an auger-hole test

piezometer or seepage tube method is more useful. Similar to the auger hole method, a cavity is excavated in the soil below the watertable. This unlined cavity is usually placed within a homogeneous layer in the soil at the lower end of a lined hole (piezometer). Water is removed several times to eliminate the effect of sealing along the walls of the unlined cavity that may have occurred during installation. The level of water in the lined hole is allowed to equilibrate and is then altered via depletion (removing water) or recharge (adding water) while its recovery is monitored over time (Fig. 2.4). Hydraulic conductivity (m s^{-1}) is calculated using the formula,

$$K = A/FT_o$$

where A is the cross sectional area (m^2) of the piezometer, F is a shape factor, and T_0 is the basic time lag (s). The shape factor, F, is calculated using,

$$F = 2\pi L/\ell n(L/R)$$

where, L - length of the uncased cavity (m)

R - radius of the uncased cavity (m).

Hvorslev (1951) defined the basic time lag, T_0, as the time (t) required to equalize the difference in hydraulic head when the original rate of flow at t_0 is maintained. It is obtained by plotting the head ratio on log scale aginst t on an arithmetic scale and determining t when the head ratio is 0.37.

Field methods of measuring K in peat are preferred since measurement in-situ allows the effective sample size to be large enough to account for local variations in composition, it reduces mechanical disturbance to the sample and generally does not affect the moisture profile of the peat

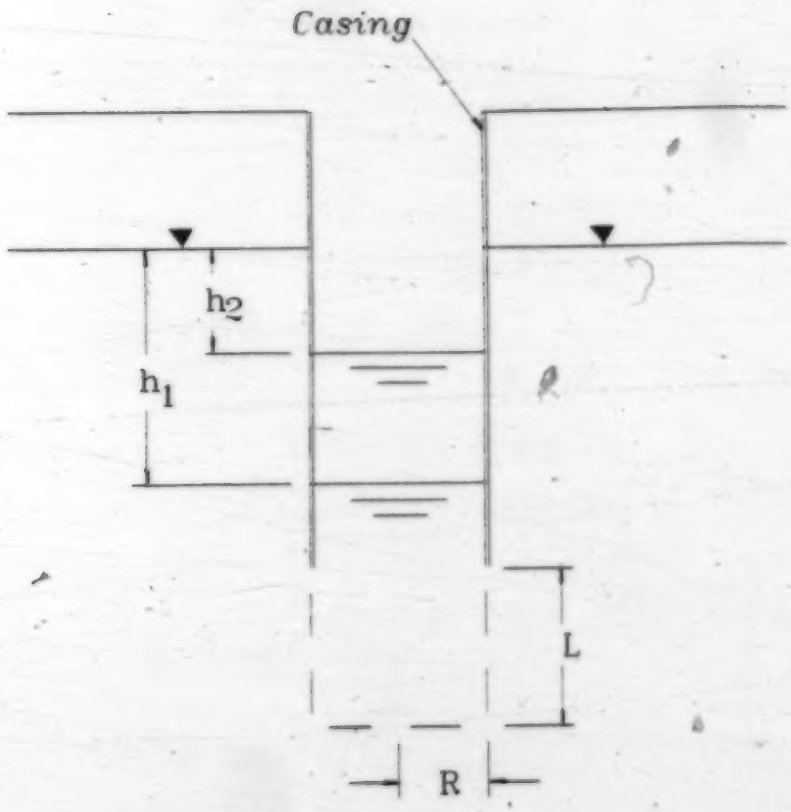


Figure 2.4 Geometry of a piezometer test

(Rycroft et al 1975a). As to which method to use - the auger-hole or piezometer - the literature does not indicate consistent use of either method. It appears European investigators prefer the auger hole method and North American investigators prefer the piezometer method (Rycroft et al 1975a).

Selection of the method to measure K in-situ should depend on the nature of the flow medium or, in other words, the degree of anisotropy and heterogeneity in the soil (peat) profile. An important consideration with both methods relates to the problem of establishing and maintaining the dimensions of an unlined cavity in rather unstable soil such as peat (Irwin 1970). Although Luthin (1957) and, more recently, Topp and Sattlecker (1983) developed variations to the auger hole method for layered, anisotropic soils, the auger hole method is not as suitable as the piezometer method for measuring K in these types of soils. In peat, Rycroft et al (1975a) noted the use of the auger hole method on an intact raised bog was affected by dominantly higher conductivity of the live moss layer (acrotelm). Similarly, Gebhardt (1967 cited by Rycroft et al 1975a)found that the auger hole method was not suitable for Phragmites spp. and brushwood peats since values for K were generally higher compared to K values from piezometer measurements. It appears the use of the auger hole method for determining K in peat should be confined to shallow peatlands where there is negligible difference among soil horizons in terms of their anisotropy and heterogeneity.

For most peats, the piezometer method allows greater flexibility in that values can be obtained for directional components of K and for individual layers. If the ratio of cavity length to radius is near

unity, vertical K is measured; if, however, the ratio of cavity length to radius exceeds unity, horizontal K is measured. Dai and Sparling (1973) recommend that the length of the unlined cavity should be at least 0.10 m for bog peatlands and greater than 0.20 m for fen peatlands. The configuration of the unlined cavity will ultimately depend on the nature of the soil profile and the type of information desired.

2.3 Hydraulic Conductivity of Peat

Table 2.1 summarizes values of K determined in-situ for various peats. Except for results from Sturges (1968), values of K for peat range from 0.01 to 60.0 x 10^{-5} m s^{-1} with the auger-hole method yielding higher results. However, as noted by Rycroft et al (1975a), comparison of K values is difficult because of varying degrees of anisotropy and decomposition in the peats examined (Table 2.1), different effective soil volumes with each method and use of different head losses in supposedly comparable tests. This is especially evident in the review presented by Walmsley (1977) where the method used to determine K is not specified or, in some cases, not enough information is provided that adequately characterizes the material.

The degree of anisotropy in peat depends on peat type and its degree of decomposition (Table 2.2). Peat dominantly comprised of undecomposed moss typically has a loose, fibrous structure with corresponding vertical K greater than horizontal K. Undecomposed herbaceous peat, on the other hand, is characterized by a compact, laminar structure where horizontal K is greater than vertical K. Although Boelter (1969) found no significant

Table 2.1 Summary of in-situ values of hydraulic conductivity for peat

Reference	Method	Material	Hydraulic conductivity ($x10^{-5}$ m s^{-1})
Baden & Eggelesmann (1961)	Auger hole	Alnus-brown moss+-Carex	0.5
		Equisetum-brown moss-Carex	3.0
Romanov (1968)	Auger hole	Fen: H1-2++	5.0
		H3-5	0.8
		H6-0	1.0
Baden & Eggelsmann (1963)	Auger hole	Sphagnum, H3-5	0.1
		Brown moss, H3-5	0.4-2.0
		Carex, H3-5	0.8-3.0
		Phragmites, H3-5	1.0-5.0
Mathur & Levesque (1985)	Auger hole	Fen: Om, 0-60 cm depth	6.0
Boelter (1965)	Piezometer	Sphagnum, H1-2 15-25 cm depth	40.0
		Sphagnum, H1-2 45-55 cm depth	1.0
		Sphagnum, H3-5 woody, 35-45 cm depth	0.1
		Herbaceous H3-5, 70-80 cm depth	0.008
Sturges (1968)	Piezometer	H6-8 46 cm depth	0.0003
		H6-8 91 cm depth	0.0002
Yamamoto (1970)	Piezometer	Undisturbed peat bogs	0.01-0.1
Dai & Sparling (1973)	Piezometer	Sphagnum 50 cm depth	60.0
Kcng et al (1980)	Piezometer	Fen: 0-40 cm depth	0.61
		40-120 cm depth	0.41
		120-160 cm depth	0.05
Chason & Siegel (1986)	Piezometer	Fen, 100 cm depth	1.0
		Bog, 100 cm depth	

+Brown moss peat comprises mainly the remains of hydrophytic members of Polytrichaceae and Hypnaceae.

++Ten point decomposition scale: H1 least and H10 most decomposed (von Post and Granlund 1926 cited by Clymo 1983).

Table 2.2 Summary of values of horizontal and vertical hydraulic conductivity for peat

Reference	Peat type	Degree of decomposition§	Hydraulic conductivity ($\times 10^{-5}$ m s^{-1})	
			Horizontal	Vertical
Malmstrom (1923)†	Sphagnum	H3	3.6	17.0
		H7	0.2	0.2
Sarasto (1961)†	Sphagnum	H1	89.0	45.0
		H8	0.3	0.3
	Carex	H1	27.0	28.0
		H8	0.6	0.4
Boelter (1965)†	Moss	H1-H3	150.0	96.0
		H4-H6	1.3	0.5
	Herbaceous	n/a	0.3	0.3
Boelter (1965)††	Moss	H1-H3	38.0	62.0
		H4-H6	0.2	0.5
	Herbaceous	n/a	0.8	0.8

§Ten point decomposition scale: H1 least and H10 most decomposed (von Post and Granlund 1926 cited by Clymo 1983).

†laboratory data

††field (in-situ) data

n/a not available

difference between horizontal and vertical K in the peat types he examined, other researchers (Malmstrom 1925 cited by Rycroft et al 1975a, Colley 1950) found horizontal K to be greater than vertical K for certain (herbaceous) peats. As decomposition progresses, the degree of anisotropy lessens and the ratio between horizontal and vertical K approaches unity.

Generally, values of K for slightly and moderately humified fen peats can be expected to range from 0.2 to 10.0 x 10^{-5} m s^{-1} with average values of 5.0 and 0.8, respectively (Table 2.3). For bog peat, K is more variable ranging from 0.002 x 10^{-5} m s^{-1} for highly decomposed peat to 25.0 x 10^{-5} m s^{-1} for very slightly decomposed peat.

2.4 Modelling Water Transmission in Peat

The use of models to represent or reflect the true nature of one or more aspects of a system allows an investigator greater flexibility to identify, detect and predict the behavior of that system in response to internal and external stimuli. Hall and Day (1977) proposed the modelling process consists of:

1) conjecture about the system (model components);
2) definition of the system (data collection and analysis);
3) formulation of a mathematical model (study of the system); and,
4) comparison of predicted against observed values.

The desired result should yield a model that is realistic and representative, simple, sensitive to change, accurate, and adaptable.

Modelling can include either theoretical or empirical relationships. A theoretical model uses causal relationships among variables and

Table 2.3 Expected values of hydraulic conductivity for different kinds of peat in the catotelm of undrained mires†

Peat type	Hydraulic conductivity ($\times 10^{-5}$ m s^{-1}) Average	Range
Fen peat:		
Slightly humified (25-30%)††	5.0	2.0 - 10.0
Moderately humified (40-55%)	0.8	0.2 - 2.0
Bog peat:		
Very slightly humified (0-10%)	15.0	10.0 - 25.0
Slightly humified (10-20%)	4.0	2.0 - 7.0
Moderately humified (35-45%)	0.5	0.2 - 1.0
Highly humified (55-65%)	0.05	0.002 - 0.08

†Adapted from original table by Ivanov (1981)
††Degree of humification follows Anon (1976).

measured rates to provide insight into the operation of the system. A theoretical model cannot be proven incorrect, only invalid. An empirical model, on the other hand, does not attempt to explain causal relationships among variables but only provides a means for reproducing or predicting system behavior. There are various modifications to the two basic approaches; for instance, theoretical or empirical models can contain both deterministic (systematic) and stochastic (random) components. The reader is referred to Weigert (1975) and Hall and Day (1977) for more thorough modelling discussions and applications.

Numerous theoretical and empirical approaches to modelling water transmission in porous media have been documented. In terms of theoretical models, Scheidegger (1974) reviews three of the most common approaches; those based on bundles of straight, parallel or branching capillary-sized tubes; those using the concept of hydraulic radius; and those models incorporating the concept of frictional drag or resistance to flow. The major drawback of these approaches is the inability to adequately define pore geometry - whether it be the area or length of capillaries, the surface available for flow or the resistance of the surfaces to flow. In addition, because of the randomness of pore geometry can one predict the behaviour of a highly chaotic system? What usually results is simplistic treatment of a highly complex situation that results in models with limited applicability.

Empirical approaches, perhaps, have fared better. By not attempting to explain relationships, it is much easier to insert or modify terms in the model as long as better predictive ability is achieved. The most obvious drawback is that causal relationships are difficult to define

especially when attempting to link microscopic characteristics of the porous medium to macroscopic flow. There are numerous examples of correlations among certain characteristics of porous media. For instance, between porosity and K (Franzini 1951 cited by Scheidegger 1974), grain size distribution and K (Scheidegger 1974) or grain orientation and K (Griffiths 1952 cited by Scheidegger 1974). In most instances, a simple causal relationship or correlation does not provide an adequate result. Consequently, researchers have recently used regression or curve-fitting techniques. Some examples: Murali et al (1979) who predicted K using sand, organic matter, clay and free oxide contents; King and Franzmeier (1981) who estimated K using morphological (structure, horizon development) and genetic (parent material) information; or, Puckett et al (1985) who relied on morphometric (void pattern, biopores), physical (porosity, density) and genetic (texture, parent material, horizon development) information to predict K. Use of these techniques can yield a model with good predictive ability yet application of the model can prove unwieldy if a large number of variables are used.

Attempting to model water transmission in peat will probably yield better results if a regression or curve-fitting approach is used. This is because peat tends to be more structurally complex than most mineral soils. It is composed of a variety of plant structures ranging from bryophytes to remains of woody plants, each having different physical properties. Unlike mineral soils, bryophytic constituents in peat have varying degrees of intracellular porosity; that is, they are permeable to water at the molecular scale. More massive structures, such as large

herbaceous rhizomes, twigs, branches or stems of trees tend to distort the strata allowing, in some cases, a continuous system of voids. Occurrence of these structures varies within a mire. Vertical variability is associated with hydrosere succession (Walker 1970 cited by Rycroft et al 1975a), while horizontal variability is due to a mosaic of plant assemblages - their occurrence governed by the hydrogeological setting of the mire. Consequently, it would be difficult, if not impossible, to derive a theoretical model predicting water transmission through peat. The simplification needed to treat flow mathematically would most likely result in a poor relationship between predicted and actual flow.

In order to empirically model water transmission in peat, the system the model represents must be defined and quantified with respect to geographic location and temporal variation. Two vertical zones can exist in peatlands - the acrotelm and catotelm. The acrotelm occurs near the surface, comprises the living plant layer and is the most biologically active zone. The catotelm occurs below the acrotelm and usually contains the bulk of peat within the mire. Romanov (1968) indicated that for a given mire, K of the acrotelm exceeds the catotelm by one to four orders of magnitude. Consequently, the acrotelm exerts an important control on water movement into and out of the mire. In context with the stated objectives, emphasis will be placed on predicting K within the catotelm during a defined time interval. The reader is referred to Romanov (1968) for more detailed discussion of seepage in the acrotelm.

Conductivity in the catotelm has been correlated with various attributes. Ingram (1983) lists some of these:

1) botanical composition - Phragmites spp.(most permeable) > Carex spp. > hynoid mosses > Sphagnum spp.(least permeable);
2) the degree of decomposition;
3) bulk density - varies inversely with K;
4) fiber content - positive correlation with K (Boelter 1965, 1969, 1970);
5) substance volume (total porosity) - varies inversely with K (Baden and Eggelsmann 1963);
6) drainable porosity or specific yield; and,
7) surface loading.

There have been few documented instances where an attempt has been made to rank the importance of these factors in predicting K and to incorporate them into such a model. Rycroft et al (1975a) indicate that decomposition hampers any attempt to quantify structural diversity occurring in peat. Ivanov (1981) is more succinct. He conveys that the degree of humification is the fundamental physical criterion for determining K and that, given a certain degree of humification, differences in floristic composition have less effect on K than differences in position within the catotelm.

Any modelling attempt to predict K in peat must quantify both decomposition and external pressure exerted on the matrix at that location within the catotelm. The variables chosen must be responsive enough to detect subtle differences in these attributes in order to identify patterns in K. Other variables quantifying an attribute of

the peat matrix that is not so much influenced by decomposition or local variations in hydrostatic pressure (e.g. wood content, mineral inclusions) should also be given consideration.

2.5 Summary

It has been documented by several researchers that in highly decomposed peats, non-Darcian flow occurs. This has been attributed primarily to the interaction between soil water and the peat matrix; specifically, through "structuring" of water within the vicinity of soil colloids and/or through accumulation of gaseous (decomposition) byproducts in the pores. Inappropriate specification of boundary conditions for (steady-state) methods of measurement also contribute to perceived non-Darcian flow in peat. Because of the compressible nature of peat and its high water holding capacity, imposition of a hydraulic gradient during the in-situ measurement causes changes in moisture in the peat within the vicinity of the cavity. Consequently, re-establishment of the equilibrium water level occurs over a shorter time interval and can result in K being overestimated by as much as two orders of magnitude.

In slightly to moderately decomposed peats, description of flow follows Darcy's linear flux-gradient relationship. Within the catotelm, K depends on the peat's botanical composition, degree of decomposition, bulk density, fiber content, substance volume (total porosity), drainable porosity or specific yield and surface loading. Typical values for K in

slightly to moderately humified fen peat range from 0.2 to 10.0 x 10^{-5} m s^{-1}. For slightly to moderately humified bog peat, K ranges from 0.2 to 25.0 x 10^{-5} m s^{-1}.

Approaches to modelling K in peat can be theoretical or empirical. Because of the structural diversity of peat and the confounding effect of decomposition on the peat matrix, theoretical description of flow would be too complex mathematically and require too much simplification to yield any meaningful predictive capability. Empirical models relying on previously documented correlations of certain matrix attributes to flow may yield better results yet have limited applicability to different types of peat. There have been few documented attempts at integrating and ranking the factors that influence K. It may turn out that an empirical model that has good predictability with respect to K may require too many variable inputs and thus be too cumbersome to use.

3.0 Materials and Methods

3.1 Study Area

In 1985, the Forest Research Branch of Alberta Forestry, Lands and Wildlife entered into an agreement with the University of Alberta to conduct research into surface drainage of forested peatlands. This study, in co-operation with the Alberta Research Council, represents a portion of the overall research commitment. The site selected for study (Plate 3.1) is situated within a peatland (fen) complex (587 $\pm$ 2.2 m AMSL), 36 km southeast of Lesser Slave Lake, Alberta in Sections 8, 9, 16 and 17, Tp. 71, R2, W5 Mer. (55° 10' N, 114° 15'W).

The study area occurs at the margin of a series of well-dissected, irregular uplands (700-1200 m AMSL) to the west and a gently descending alluvial valley (610 m AMSL) to the east and northeast. Bordering uplands are underlain by the Cretaceous Wapiti Formation - typically, gray feldspathic, clayey sandstone and bentonitic mudstone with scattered coal beds. Underlying the fen complex is a fine-grained, glaciolacustrine blanket (< 8 m) over approximately 65 m of glacial till (as ground moraine) containing interspersed gravel lenses of varying thickness (Toth and Gillard 1984). This till deposit is a component of the High Prairie Buried Valley system: a major preglacial drainage system that enters southwest of Smith and drains west under Lesser Slave Lake to High Prairie (Vogwill 1978).

Climate is sub-artic (Koppen 1923); that is, cool, short summers with one to three months of temperatures above 10°C. Average January and

Plate 3.1 Aerial photograph(1:40,000, 1987) of the study site. Study site outlined:photograph after drainage.

July temperatures (1931-1960) are -16°C and 16.5°C, respectively (Atlas of Alberta 1969). Mean annual precipitation is 460 mm with the majority occurring between April and August.

Vegetation is characterized by forest cover consisting of black spruce (Picea mariana (Mill.) B.S.P.), tamarack (Larix laricina (DuRoi K. Koch) and bog birch (Betula glandulosa Michx.). Ground cover comprises mostly brown mosses (e.g. Brachythecium furdigum (C.J. Hartm.) Kindt., Plagiomnium ellipticum (Brid.) Kp. Drepanocladus spp., Calliergon giganteum (Schemp.) Kindt, Bryum pseudotriquetrum (Hedw.) Gaertner), Sphagnum warnstorfii (Russow) and Carex spp. (Harkonen 1985).

Surface water chemistry within the study area is presented in Table 3.1. Dominant constituents are calcium, magnesium and bicarbonate, which is in agreement with Vogwill's (1978) findings for shallow groundwater in the Lesser Slave Lake area. Using Vitt's (1986) guidelines for peatland classification, the study area is dominantly transitional fen with moderate minerotrophy.

3.2 Field Procedures

3.2.1 Sampling and Implications on Statistical Analyses

Sample locations were determined systematically using a grid with 200 m spacing (Figure 3.1). This sampling design was followed because:

1. data used in this study originated from earlier research (Toth and Gillard 1984) initiated on the site,
2. there was not a priori evidence suggesting regular periodicities in peat properties coincided with the sampling interval, and,

Table 3.1 Surface water chemistry within the study site (n = 30)

Parameter	Mean Concentration	Standard deviation	Range	Percent of total EPM†
		mg L^{-1}		
Calcium	19.7	13.1	11.0-77.0	38
Magnesium	4.7	2.1	3.0-13.0	15
Potassium	0.1	0.03	0.1-0.2	1
Sodium	3.6	0.7	2.7-6.2	6
Sulfate	0.4	0.2	0.3-1.0	1
Phosphorus	0.1	0.03	0.1-0.2	1
Chloride	0.7	0.6	0.5-3.7	1
Nitrate	0.1	0.0		1
Bicarbonate	60.6	22.4	22.0-111.0	39
pH	6.4	0.3	5.8-7.2	
Electrical Conductivity (uS/cm)	98.6	50.6	62.0-321.0	

† equivalents per million

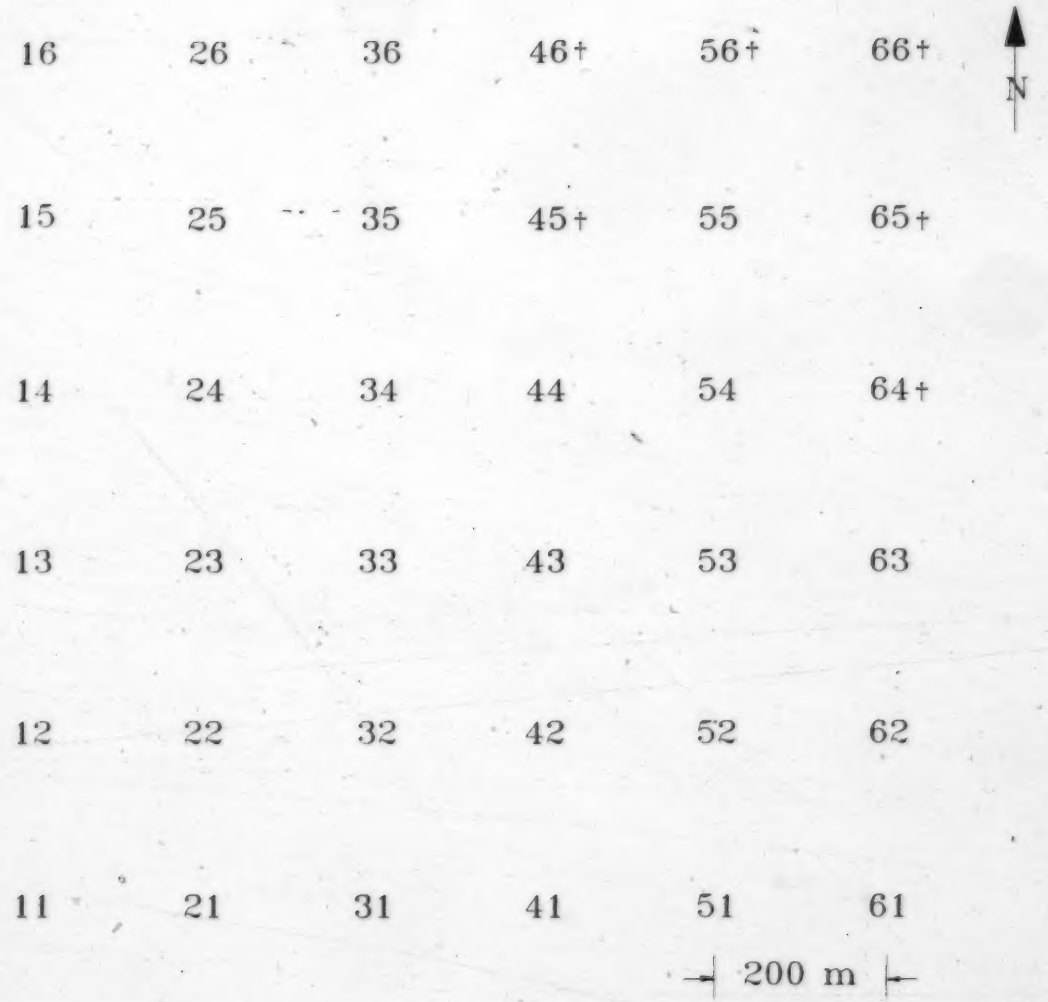


Figure 3.1 Sampling locations. † grid points not sampled.

3. an estimate of sampling error (Webster 1977) was not required.

As part of a co-operative project, a detailed soils inventory (1:10,000) was conducted by the Alberta Research Council (see Turchenek et al 1984). With the aid of aerial photographs and soil investigations, the study site was delineated into 14 map units consisting of areas of mineral soil, swamp, fen and bog. Only areas classified as horizontal fen were sampled. Grid point locations 45, 46, 56, 64, 65 and 66 (Figure 3.1) were not included because at these locations soils were transitional between organic and mineral.

In-situ K measurements were determined at each sample location at depths of 1, 2 and 3 m depending on peat thickness. A one meter distance between the hydraulic conductivity cavities (i.e. one per depth) was needed to ensure that the drawdown of the watertable during the test did not significantly change moisture storage of peat within the vicinity of the unlined cavity. Since the depth of peat was variable across the site, an unequal number of observations occurred at each depth; specifically, six observations were made at depths less than 1 m, 24 at 1 m, 19 at 2 m and seven at 3 m. A more continuous, normal distribution of the vertical locations where K measurements occurred was achieved from detailed survey information (Toth and Gillard 1984) by using mean sea level as a datum and expressing each measurement as elevation above mean sea level.

The experimental unit (Steele and Torrie 1980) was considered to be the peat volume near the unlined cavities previously excavated for the in-situ K measurement. Because the K measurements were made during the

summer and peat excavated from the unlined cavity was not saved, an attempt was made to sample as close as possible to the unlined cavity. Three cores were taken with a Macaulay peat sampler (Day et al 1979) at each grid point location at each depth. Two composite samples were obtained (Fig. 3.2) which represent repeated measurements on the same experimental unit (peat volume). From one composite sample (e.g. DbA) bulk density, volumetric moisture content and ash content were determined; from the other, other laboratory determinations were made. Sampling did not accommodate genetic patterns (soil horizons) in the peat profile near the unlined cavity.

3.2.2 In-situ Determination of Hydraulic Conductivity

Results from in-situ K measurements were supplied to the author by Toth and Gillard (1984). Polyvinyl chloride (PVC) tubes 10 cm inside diameter and of varying lengths were used as piezometers. A 25 cm long unlined cavity centered at the depth at which K was measured was excavated at the end of the piezometer using a Bi-partite Edelman (Dutch) soil auger. Water was removed from the piezometer and the change in water level within the tube was monitored over time. Hydraulic conductivity was calculated using,

$$K = A/FT_o$$

where K - saturated hydraulic conductivity ($m\ s^{-1}$)

A - piezometer cross sectional (m^2)

F - shape factor

T_o - basic time lag.

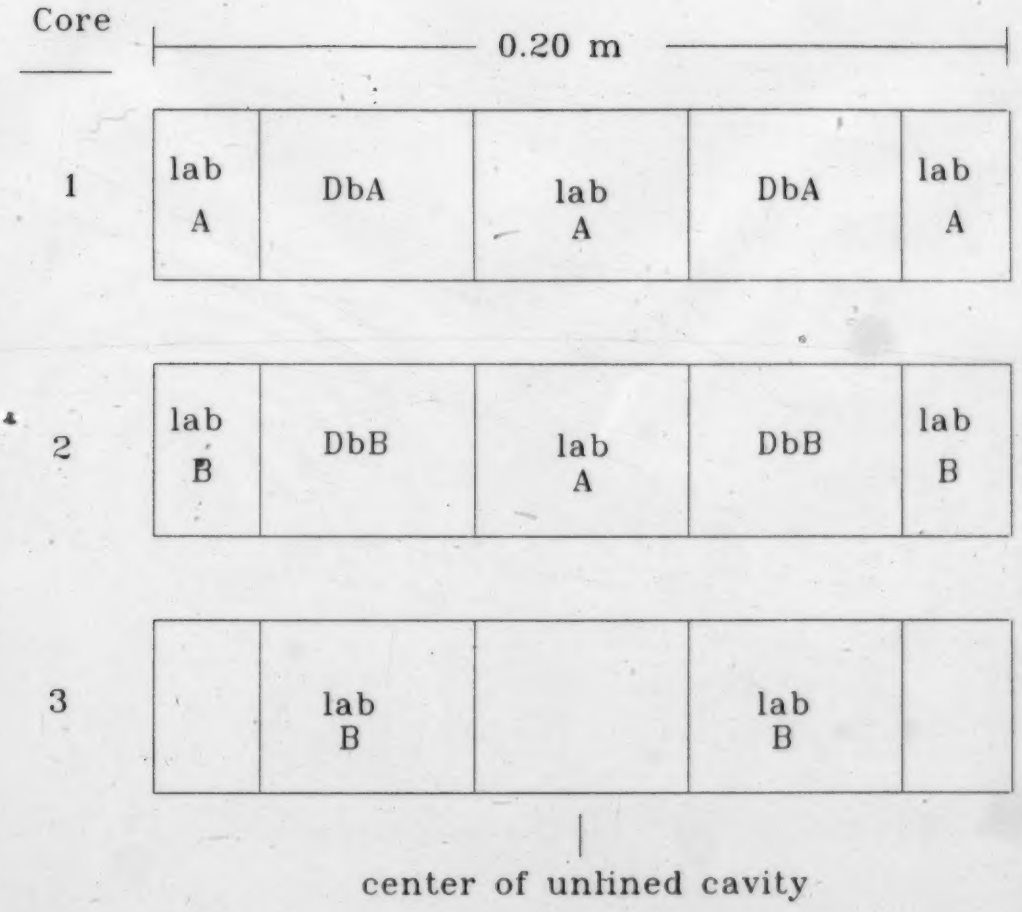


Figure 3.2 Composite sampling in the vicinity of the piezometer cavities. Duplicate subsamples A and B taken for bulk density(Db) and laboratory(lab) analyses

The shape factor, F, was calculated using the expression,

$$F = 2\pi L/\ell n(L/R)$$

where L - length of the uncased cavity (m)

R - radius of the uncased cavity (m).

The basic time lag was obtained by plotting the head ratio on log scale against t on an arithmetic scale and determining t when the head ratio is 0.37 (see Section 2.2).

3.2.3 Description and Classification of Soil Profiles

At most sampling locations, peat stratigraphy was described using criteria outlined by Turchenck et al (1984) and each profile was classified according to the Canadian System of Soil Classification (Canada Soil Survey Committee 1978). Soil horizons were delineated on the basis of differences in the degree of decomposition, structure, consistence, color, soil reaction (pH) and visual estimates of botanical composition. Profile descriptions and soil classifications are presented in Appendix 7.1.

3.3 Laboratory Analyses

Samples for bulk density and moisture content were refrigerated at 2°C; all others were frozen until analyzed. After thawing, approximately one-third was refrozen for botanical analysis, another one-third was air dried at 20°C for chemical analyses and the remaining was left in a moist state for fiber content determination.

3.3.1 Physical Analyses

Bulk density was determined using a 118 cm^3 volume and expressed on an oven dry (105°C) and ash-free basis (Nichols and Boelter 1984). From the same analysis, mass and volumetric moisture contents were also obtained.

Rubbed and unrubbed fiber contents were determined according to Sneddon et al (1971). From a uniformly hand-mixed sample, three 10 g subsamples were taken. For unrubbed fiber content, one 10 g sample was soaked overnight in 200 ml of distilled water containing 2 g Calgon (sodium hexametaphosphate) dispersant and gently washed through a 100 mesh (0.15 mm) sieve. Material retained on the sieve-minus wood fragments greater than 2 cm - was oven-dried (105°C) and weighed. For rubbed fiber content, a similar procedure was followed except the 10 g subsample was soaked overnight in 200 ml of distilled water and prior to sieving, was placed in a Hamilton Beach milk shake stirrer for 10 minutes. The third 10 g subsample was oven-dried (105°C) to determine water content so unrubbed and rubbed fiber contents could be expressed on an oven-dried basis as a percentage of total (oven-dried) subsample weight.

Particle density was determined gravimetrically using pycnometers as outlined by Blake (1965). Twenty samples were chosen and represented varying degrees of decomposition. Dry, clean 50 ml pycnometers were weighed empty (Wa), with distilled water (Ww), with soil corrected to an oven dry condition (Ws), and with soil and water (Wsw). Particle density (Dp) was calculated using,

$$Dp = (dw(Ws-Wa))/(Ws-Wa)-(Wsw-Ww)$$

where dw is the density of water (Mg m^{-3}). Porosity (f) and void ratio (e) were calculated using relationships outlined by Hillel (1971),

$$f = 1-Db/Dp \qquad \text{and} \qquad e = f/1-f$$

where Db and Dp are bulk and particle density, respectively.

3.3.2 Chemical Analyses

Samples for chemical analyses were ground in a Wiley mill to less than 2 mm except for total carbon content where peat was ground to less than 0.15 mm.

Ash content was determined gravimetrically on an oven-dried (105°C) sample by loss on ignition at 550°C until completely ashed (Andrejko et al 1971). The pH was determined potentiometrically using 3 g moist peat in 50 ml 0.01 M $CaCl_2$ (Van Lierop and Mackenzie 1977). Pyrophosphate index was determined spectrophotometrically by measuring absorbance (λ= 550 nm) of a diluted (five-fold), filtered, 0.025 M sodium pyrophosphate solution (Schnitzer and Desjardins 1965). Values represent absorbance multiplied by 100: the greater the absorbance, the more decomposed the sample is. This method is not to be confused with Lynn et al's (1974) pyrophosphate index which assesses decomposition by comparing the color of a blotted chromatographic strip with the 10YR page from a Munsell color book. Total carbon content in oven dried samples was determined by (dry) oxidation of organic and inorganic carbon in a high temperature (LECO) induction furnace (Tabatabai and Bremner 1983). Carbon levels were measured by comparing thermal conductivities of a pure O_2 stream against a CO_2-O_2 stream. Total carbon contents represent

estimates of organic carbon since pH measurements did not indicate the presence of inorganic carbonates. Total nitrogen was determined by digestion in concentrated sulfuric acid (semimicro Kjeldahl method) where liberated ammonium was converted in hot alkali to ammonia and measured using an ammonia electrode. Exchangeable acidity and cations were determined using $BaCl_2$-triethanolamine (pH 8.1) according to McKeague (1978) while cation concentrations in the leachate were obtained by ICP/AES (Fassel 1978). Cation exchange capacity (CEC) was calculated by summation according to Bache (1976).

3.3.3 Botanical Analysis

Volumetric determination of botanical constituents in the peat follows a procedure outlined by Janssens (1983) and modified by Vitt (1986). Categories for various botanical constituents - moss, herbaceous and wood - are after those presented by Largin (1979). Forest litter was added to include twigs, bark, cones and woody plant remains that did not resemble large pieces of wood originating from stems. An additional category, percent volume less than 0.5 mm, contained plant remains that were unidentifiable at a magnification of 25X.

Enumeration of botanical constituents was performed only on the volume greater than 0.5 mm. An average total volume of 93 ml (Table 3.2) was spiked with 0.5 g poppy seeds (984 ± 54 seeds), soaked 1-3 days in a non-foaming wetting agent (10% Aerosol OT), and washed through 0.5 mm and 0.15 mm sieves. Total volume and the fraction between 0.5 and 0.15 mm were determined by measuring the volume of water displaced by the

sample in an apparatus described by Janssens (1983). The fraction less than 0.15 mm was not measured and was discarded. The fraction greater than 0.5 mm was obtained by difference from the total volume and the fraction less than 0.5 mm. Since only the fraction between 0.5 and 0.15 mm was measured, the fraction less than 0.5 mm was calculated using unrubbed fiber content determined from another subsample in the relationship,

$$\text{fraction}<0.5\text{ mm} = ((100-\%\text{unrubbed fiber}/100)+ 1)A + A$$

where A represents the fraction between 0.5 and 0.15 mm. It was assumed that the volume passing through the 0.15 mm sieve during determination of unrubbed fiber content would be the same as the volume passing through the 0.15 mm sieve during determination of botanical constituents.

From an average (greater than 0.5 mm) volume of 41 ml (Table 3.2) two representative subsamples were taken and each was placed in a grooved piece of plexiglass that allowed 12 by 12 mm grids to be placed underneath it. Botanical constituents were spread along the groove and grid squares were counted and recorded for each component. The various botanical constituents were expressed as a percentage of the total area examined which was extrapolated to the volume greater than 0.5 mm. Microscopic examination was terminated after 4 grids (12 poppy seeds counted) were examined. This represented approximately 0.4 ml or 1% of the volume greater than 0.5 mm.

Table 3.2 Mean values (standard errors) for parameters associated with the botanical analysis of peat (n = 112)

Peat volume (mL)	93(±2.1)
Volume >0.5 mm (mL)	41(±1.0)
Volume enumerated(%)	1(±0.1)
Seeds counted	12(±0.6)
Number of grids examined	4(±0.0)

3.4 Data Analyses

3.4.1 Assessment of Sample Distributions

Several theoretical models have been formulated to describe empirical distributions of random samples taken from their respective populations. Of these, the normal or Gaussian function is the most commonly used parametric model to describe a sample's distribution. The normal model defines the probability of occurrence of a given value for a continuous, numerical variable assuming that the two parameters that describe the model, the mean (μ) and standard deviation (σ), are normally distributed. By ensuring that a sample's empirical distribution is similar to the normal model, test statistics can be more easily compared since their properties are summarized by the two parameters, μ and σ.

Since it was assumed that each variable's empirical distribution would be similar to the (theoretical) normal distribution, initial data analysis examined each variable's distribution for substantial departures from the normal model. Several graphical and numerical techniques were used to assess non-normality. Visual conformation to the normal distribution for each variable was through inspection of frequency histograms, normal probability plots and detrended normal probability plots (Norusis 1985b). This was supplemented with significance testing of standardized coefficients of skewness and kurtosis (Cooper and Weekes 1982) and Kolmogorov-Smirnov one-sample tests (Steele and Torrie 1980). Variables with non-normal distributions were selected for appropriate data transformations.

3.4.2 Data Transformations

From preliminary assessments, it was felt that 19 of 23 variables had sampling distributions sufficiently skewed and leptokurtic to warrant transformation. In instances where strong asymmetry is evident, Emerson and Stoto (1985) recommend using an appropriate "power" transformation to change the shape of the distribution . The family of "power" transformations can be expressed as,

$$T_{p(x)} \begin{cases} (x^p-1)/p & p\neq 0 \\ \ell nx & p=0 \end{cases}$$

where $T_p(x)$ represents the transformed variate (x) to the power of p. These transformations have the following properties:

1. they preserve the order of values in the batch;
2. the location of letter values (e.g. median) are the same in transformed versus non-transformed batches;
3. they are continuous functions; that is, points close in the non-transformed batch will be close in the transformed batch relative to the scale being used;
4. they are smooth functions: for points farther away from the mean or median, the interval will be compressed more than for points closer to the mean or median; and,
5. they are elementary functions that are easy to use.

Selection of appropriate power transformations followed a procedure outlined by Box and Cox (1964). A log likelihood function (L) is used to estimate the best transformation to normality within the family of power transformations and can be expressed as,

$$L = (-v/2)\ell nS_T^2 + ((\lambda-1)v/n)\Sigma\ell nY$$

where S_T^2 is the variance of the transformed Y values based on v degrees of freedom; λ (lambda) is the parameter which corresponds to a given power transformation (Table 3.3); and, n is the sample size. Taerum (1986) provided a $Spss_x$ procedure to obtain power transformations for 15 of the 19 variables whose distributions required transformations. For four variables (Table 3.4), transformations based on interpretation of lambda (Sokal and Rohlf 1969) were not followed; instead, Webster's (1977) guidelines for skewed percent data were used and arcsine transformations were employed.

The effectiveness of each transformation was assessed by examining the transformed variable's distribution (sec. 3.4.1) and comparing the results. With all variables except one, there was a substantial improvement in each distribution. While an improvement in skewness was primarily desired, a serendipitous effect of transformation was coincident improvement in kurtosis. Percent moss still exhibited negative skewness although its severity was lessened by transformation.

Classical statistical theory is largely based on the multivariate normal distribution. Since knowledge relating the robustness of multivariate methods to particular sample distributions is sparse (Andrews et al 1971), it was felt that interpretations from multivariate techniques employed should use data which resembles the theoretical multivariate normal distribution. Consequently, transformations were employed. However, given the statistical techniques that were used, there was not an attempt to compare interpretations using non-transformed and transformed data. Unless indicated otherwise,

Table 3.3 Lambda values and corresponding power transformations

Lambda	Transformation		Skewness
-2.0	x^{-2}	inverse square	positive
-1.0	x^{-1}	reciprocal	positive
0	$\log_{10}$	logarithmic	positive
0.5	$x^{0.5}$	square root	positive
1.0	x^{1}	linear†	--
2.0	x^{2}	square	negative

† does not change the shape of the distribution

Table 3.4 Calculated lambda values and data transformations employed

Variable	Lambda	Transformation
Ksat	0.14	$\log_{10}$
Moisture content (m/m)†	5.27	$\sin^{-1}(x/100)^{0.5}$
Bulk density	-1.22	x^{-1}
Bulk density (ash free)	-1.06	x^{-1}
Porosity†	26.24	$\sin^{-1}(x/100)^{0.5}$
Unrubbed fiber	0.44	$x^{0.5}$
Ash	-1.38	x^{-1}
Pyrophosphate index	-1.00	x^{-1}
Total nitrogen	2.86	x^{2}
C:N	-2.56	x^{-2}
Exchangeable hydrogen	0.34	$x^{0.5}$
Exchangeable calcium	-1.37	x^{-1}
Exchangeable magnesium	1.80	x^{2}
Exchangeable aluminum	-1.41	x^{-1}
CEC	-1.26	x^{-1}
Moss†	0.14	$\sin^{-1}(x/100)^{0.5}$
Wood	0.53	$x^{0.5}$
Forest litter†	0.3	$\sin^{-1}(x/100)^{0.5}$
Volume 0.5 mm	2.91	x^{3}

†guidelines for interpretation of lambda (Sokal and Rohlf 1969) not followed; arcsine transformation advocated by Webster (1977) for percent data used instead.

use of the following statistical techniques assumes a multivariate normal distribution, with homogenous error distributed normally.

3.4.3 Statistical Analyses

For each variable except K and elevation, values from the two composite samples that were obtained in the vicinity of each cavity (Fig. 3.2) were averaged to obtain a value for that peat volume. Unless indicated, all statistical analyses use a sample size (n) of 50 cases. Results for various statistical procedures were obtained using Version 2.1, $SPSS_x$ (Spss Inc. 1983) supported by the University of Alberta computing facilities.

3.4.3.1 Analysis of Variance

One-way analysis of variance (ANOVA) and significance tests for polynomial trends were carried out for each variable across each depth class sampled. Four depth classes were created based on the depth at which the middle of the cavity occurred in the piezometer test (Table 3.5). Following Steele and Torrie (1980), the linear model used was,

$$Y_{ij} = \mu + \tau_i + \varepsilon_j$$

where Y_{ij} is the observed value; μ the grand mean; τ_i is fixed and represents the depth class; and ε_j is random error. Since there are an unequal number of observations in each depth class and there are not equal intervals between depth classes (Table 3.5), depth class one was not included in the ANOVAs performed and significance testing for linear and quadratic trends used weighted polynomial contrasts (Sokal and Rohlf 1969, Norusis 1985a). Box plots (Emerson and Strenio 1985) were also examined as visual aids to interpretation of significant polynomial trends.

Table 3.5 Depth class limits and widths

Depth class	Number of observations	Class limit (m)		Class width (m)
		Upper	Lower	
1	6	0.7	0.94	0.24
2	24	1.02	1.06	0.04
3	19	1.94	2.00	0.06
4	7	2.86	2.88	0.02

3.4.3.2 Pearson Product Correlations

Zero-and first-order correlations were generated among all variables and for selected variables, respectively, using both transformed and non-transformed data. Use of transformed data is supported by Kowalski (1972) who concludes that the distribution of r, the correlation coefficient, is quite sensitive to non-normality and becomes less stable with increasing values of rho (ρ), the population correlation coefficient. In the majority of correlations examined, use of transformed data resulted in higher values of r with corresponding higher levels of significance compared to correlations using non-transformed data. In some instances, however, transformation compressed the range in values to the extent that a change in the direction and magnitude of r occurred that was intuitively unrealistic.

3.4.3.3 Principal Components Analysis

Principal components analysis (PCA) is an exploratory technique for assessing the interdependence among a set of variables. It is a form of factor analysis and consists of transforming the original set of variates into another set of (component) variates that have the following properties: they represent linear composites (functions) of the original variates; they are independent (orthogonal) of each other; and, the total variation represented by the component variates is equal to the total variation represented by the original variates (Isebrands and Crow 1975). The Z^{ith} component can be represented as,

$$Z^{ith} = a_1x_1 + a_2x_2 + \ldots + a_jx_p$$

where a_j is a linear (eigenvector) coefficient relating (loading) a given variable to the component and x_p is the original variable (Pielou 1984). The first component represents a set of variables that account for more variance in the data than any other linear combination of variables. The second component represents another linear combination of variables that account for the most variance in the data after the effect of the first component is removed; that is, the second component is independent or orthogonal to the first component. Given p variables in the data, p components are extracted until all variance in the data is allocated to these components.

In this study, PCA was used to determine interrelationships among the variables and provide guidelines for selection of variables to be used in regression analysis. Because of the different units of measure among variables used in PCA, a correlation matrix was used (Pielou 1984). Components were retained based on their respective eigenvalues being greater than one (Jeffers 1964) and through visual examination of a plot of the variance accounted for by each component against the number of components (Cattell 1966).

Extracted components were not rotated since it was perceived that interpretability would not be improved; that is, there were definable clusters of variables associated with only one component (Thurston 1947). Initially, 29 variables were included in PCA. Unsatisfactory results were obtained because the correlation matrix used in the analysis was singular; that is, the determinant equalled zero and a unique inverse did not exist. Consequently, variables were excluded from further analyses on the basis of obvious relationships to other variables (e.g. porosity and void ratio). Fifteen variables were excluded leaving fourteen for

subsequent analyses: bulk density (ash-free), volumetric moisture, K, rubbed fiber, unrubbed fiber, ash, exchangeable aluminum, pyrophosphate index, CEC, C:N, moss, wood, herbaceous content and elevation.

3.4.3.4 Regression Analysis

Multiple linear regression analysis is a procedure that permits estimation of one (dependent) variable by one or more (independent) variables using linear or nonlinear functions. The general model can be presented as,

$$Y = B_0 + B_1X_1 + B_2X_2 + \ldots B_pX_p + \varepsilon$$

where Y represents the estimated value for the dependent variable; B_0, B_1, B_2 . . . B_p are unknown (least square) estimators; X_1, X_2, . . . X_p are observable (independent) variables; and, ε is randomly distributed and independent error (Draper and Smith 1966). In addition to the assumptions concerning the nature of each variable's distribution (Section 3.4.2), it is assumed that the independent variables are not fixed but are subject to random variation (Steele and Torrie 1980).

In conjunction with PCA, a subset of independent variables characterizing site and peat attributes was used to estimate the dependent variable, K. Ideally, in regression analysis only influential variables should be included and there should be enough variables to obtain a reasonable fit for predictive purposes (Draper and Smith 1966). Use of PCA to select variables for a regression equation has been reported by Kendall (1957), Beale et al (1967), Jeffers (1967) and Jollife (1972). Of these, a variation of Jollife's (1972) approach was

used. Originally, Jollife's approach consisted of selecting those variables that load the highest on components whose eigenvalues exceed an arbitrary value. In order to provide for selection of more than just four variables, variables whose loadings were greater than or equal to 0.60 on components whose eigenvalues exceeded one were retained for regression analysis.

Following Hocking (1976), a stepwise computational procedure was used to determine independent variables in the regression equation. The decision to retain a particular variable in the model was based on the magnitude and significance of the increase in fit (R^2) brought about by the variable's entry into the model (Hocking 1976). Consequently, when inclusion of a variable in the model resulted in a small, insignificant increase in R^2, variable selection and model formulation stopped.

Analysis of differences between predicted and observed values (residuals) was performed to validate assumptions associated with multiple linear regression (Draper and Smith 1966). Graphical techniques were used to assess the degree of normality, independence and homoscedasticity (homogenous variance) of the error component and linearity of the systematic component. Several visual plots were examined: histogram and normal probability plots of the standardized residuals; a scatterplot of standardized predicted vs. residual values; standardized scatterplots of observed values for individual variables against residual values; and standardized partial regression plots of observed values for independent variables in the equation against residual values.

The shape of the distribution of residuals was ascertained through inspection of a histogram and normal probability plot. Patterns evident

in the histogram are confirmed by a normal probability plot; that is, in a plot of standardized residuals against (expected) theoretical values, deviations of plotted values from the line representing a perfect distribution correspond to skewness, kurtosis and/or discontinuities (modes) in the observed distribution. Independence and homogeneity in the error component was assessed by first examining a plot of standardized predicted vs. residual values and then plots of residual values against standardized observed values for each variable in the equation. Randomly scattered points in a band across the plot indicate the assumptions have not been severely violated. The nature of the relationship between each independent variable and the dependent variable was examined using standardized partial regression plots (Norusis 1985b). Residual values calculated from the equation not including the variable in question are plotted against residual values calculated from the complete equation. A strong linear relationship between independent and dependent variables corresponds to a narrow, straight band of points oriented at a slope equal to the magnitude of the regression coefficient for that variable in the equation. The reader is referred to Anscombe and Tukey (1963) or Draper and Smith (1966) for examples of patterns that typically occur in plots associated with residual analysis.

3.4.3.5 Trend Surface Analysis

First order trend surface analyses were used to determine if significant linear patterns occurred across the study site for peat thickness and variables in the equation. Because of the small number of observations at depths less than 1 m (n=6) and at 3 m (n=7), trends

could only be identified at 1 and 2 m depths. There was no attempt to fit higher order functions (e.g. quadratic, cubic) to the data.

Trend surface analysis is an extension of multiple linear regression (MLR). Similar to MLR, the value of each observation depends on a systematic or trend component assumed to operate over the area considered for study and a non-systematic or error component assumed to arise from local fluctuations (Krumbein and Graybill 1965). The model for a first order (linear) trend analysis can be expressed as,

$$Z = B_0 + B_1X_1 + B_2Y_2 + \varepsilon$$

where Z represents the dependent variable; B_0, B_1 and B_2 are calculated trend (regression) coefficients; X_1 and Y_2, geographical (Cartesian) coordinates; and, ε, random error. Goodness of fit is assessed by the percentage of variation accounted for by the trend and is analogous to the coefficient of determination (R^2) used in MLR. Significance of the trend was tested using the F statistic; individual coefficients in the equation were not tested. Confidence surfaces (Krumbein 1963) associated with each trend were not calculated since trend surface analysis was only used to aid interpretation of the model predicting K.

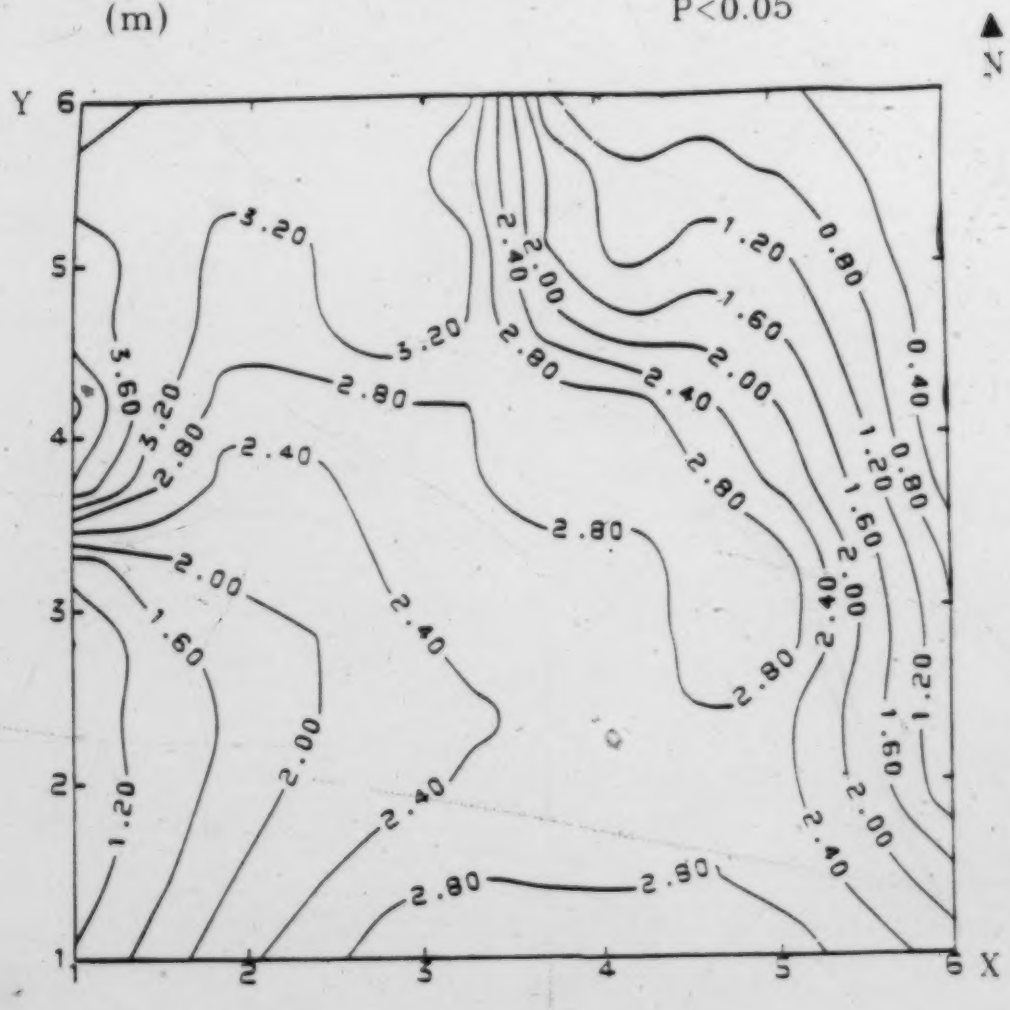
4.0 Results and Discussion

4.1 Peat Characteristics

Within the study site, the depth of peat ranges between 0.40 and 4 m (Fig. 4.1). Turchenek et al (1984) identified three wetland types occurring on the site: horizontal fen, swamp and bog. Dominant subgroups include Terric and Typic Fibrisols and Mesisols with various integrades between the two (Fig. 4.2). Near the southwestern and northeastern margins of the site, limited areas of mineral soil occur as (peaty) Orthic Luvic Gleysols.

Peat examined in this study is moderately decomposed, dominantly herbaceous-wood in composition and has a relatively high trophic status (Table 4.1). Based on rubbed fiber contents, almost all soil horizons in the vicinity of the piezometer cavities were classified as Om (Canada Soil Survey Committee 1978). However, at the 2 m depth (depth class 3) the peat was consistently different in degree of decomposition, botanical composition and trophic status from peat sampled at other depths. Higher rubbed fiber contents, amounts of moss, lower levels of exchangeable calcium and magnesium, and less wood (Tables 4.1 and 4.2) indicate a more fibric peat occurred at the 2 m depth in a layer that extends through most of the study site. These differences with depth are also evident upon examination of other variables such as moisture content, pyrophosphate index, ash and total nitrogen content.

depth = 3.4 - 0.3X - 0.05Y R^2=0.21
(m) P<0.05



Scale 1:8000 Contour Interval 0.4 m

Figure 4.1 Peat thickness across the study site

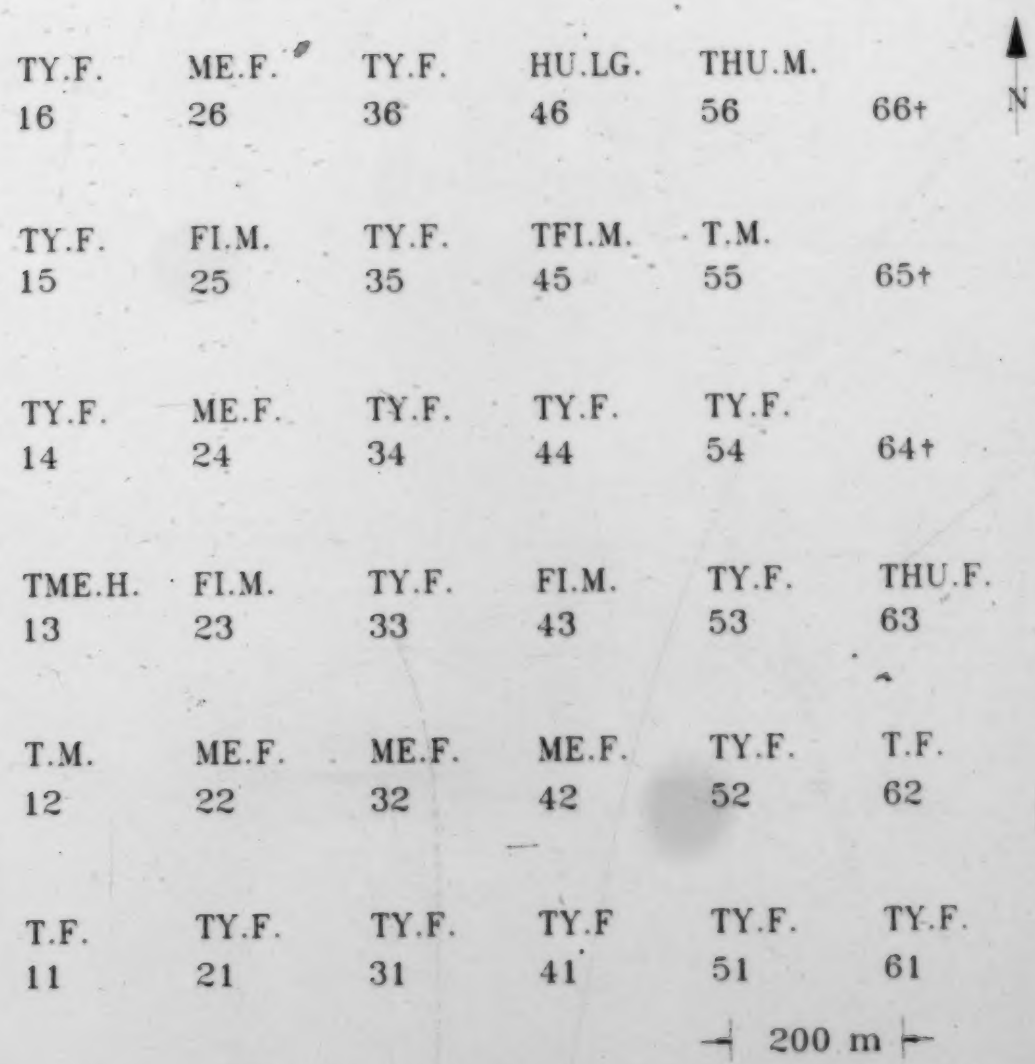


Figure 4.2 Soil subgroups occurring within the the study site. †grid points not classified.

Table 4.1 Mean values (coefficients of variation) for selected properties

Variable	Unit	Depth class 1 (n = 6)	2 (n = 24)	3 (n = 19)	4 (n = 7)	Site (n = 56)
Hydraulic conductivity	$m\ s^{-1}(x10^{-5})$	1.04 (53)	1.78 (81)	1.34 (54)	0.77 (93)	1.42 (78)
Moisture	$m^3 m^{-3}$	0.77 (9)	0.84 (3)	0.89 (4)	0.90 (4)	0.86 (6)
	$kg\ kg^{-1}$	4.86 (10)	6.60 (8)	7.24 (10)	5.97 (6)	6.55 (14)
Bulk density	$Mg\ m^{-3}$	0.16 (15)	0.13 (9)	0.12 (14)	0.15 (8)	0.13 (14)
Bulk density (ash free)	$Mg\ m^{-3}$	0.14 (15)	0.12 (8)	0.12 (12)	0.13 (8)	0.12 (13)
Porosity	%	90 (2)	92 (1)	92 (1)	90 (1)	91 (1)
Void ratio		9 (16)	11 (9)	11 (14)	10 (10)	11 (14)
Unrubbed fiber	%	52 (11)	58 (6)	66 (9)	59 (15)	60 (12)
Rubbed fiber	%	22 (12)	29 (13)	37 (12)	28 (20)	31 (21)
Ash	%	12 (18)	8 (14)	7 (22)	11 (18)	8 (28)
Pyrophosphate index		75 (41)	10 (53)	9 (22)	19 (14)	18 (126)
Total carbon	%	52 (3)	55 (1)	55 (1)	54 (2)	54 (2)
Total nitrogen	%	2.08 (12)	2.17 (11)	2.02 (12)	2.27 (11)	2.12 (12)
C:N		22 (8)	24 (14)	26 (14)	21 (8)	24 (14)
pH($CaCl_2$)		5.2 (5)	5.2 (2)	5.2 (2)	5.2 (3)	5.2 (3)
Exchangeable hydrogen	$cmol(+)kg^{-1}$	88 (20)	75 (10)	75 (10)	78 (20)	77 (14)
Exchangeable calcium	$cmol(+)kg^{-1}$	142 (27)	138 (10)	112 (9)	140 (12)	130 (16)
Exchangeable magnesium	$cmol(+)kg^{-1}$	12 (14)	16 (10)	13 (15)	14 (12)	14 (16)
Exchangeable aluminum	$cmol(+)kg^{-1}$	2.4 (17)	1.2 (20)	1.2 (37)	1.3 (18)	1.3 (38)
Exchangeable sodium	$cmol(+)kg^{-1}$	0.4 (18)	0.4 (25)	0.5 (24)	0.5 (4)	0.4 (28)
Exchangeable potassium	$cmol(+)kg^{-1}$	0.08 (34)	0.07 (6)	0.07 (1)	0.07 (1)	0.07 (14)
CEC	$cmol(1/2Ba^{++})kg^{-1}$	244 (7)	228 (7)	202 (7)	234 (10)	222 (11)
Moss	% (v/v)	2 (119)	4 (65)	17 (45)	1 (131)	8 (110)
Herbaceous	% (v/v)	11 (29)	16 (37)	20 (32)	16 (47)	17 (39)
Wood	% (v/v)	13 (28)	11 (22)	5 (49)	12 (65)	9 (50)
Forest litter	% (v/v)	1 (74)	4 (58)	2 (79)	5 (68)	3 (76)
Volume < 0.5 mm	% (v/v)	73 (4)	65 (12)	56 (19)	66 (11)	63 (16)
Elevation (add 580 m)	m	7.8 (1)	7.6 (1)	6.7 (1)	5.9 (1)	7.1 (1)

Table 4.2 F values from one-way analysis of variance and polynomial contrasts by depth class

Variable	ANOVA	Polynomial contrasts		Heterogeneity of variance (Box F)
		Linear	Quadratic	
Hydraulic conductivity†	5.55(**)	8.51(**)	2.59(n.s)	2.26(n.s)
Moisture content: ($m^3\ m^{-3}$) †	22.01(**)	40.03(**)	3.98(*)	2.56(*)
($kg\ kg^{-1}$)	12.69(**)	0.31(n.s)	25.06(**)	2.42(*)
Bulk density †	7.34(**)	4.27(**)	10.40(**)	2.52(*)
Bulk density (ash-free)†	4.53(**)	2.88(*)	6.18(**)	1.96(n.s)
Porosity †	6.68(**)	9.78(**)	3.58(*)	2.01(n.s)
Void ratio	6.23(**)	8.04(**)	4.41(**)	2.04(n.s)
Unrubbed fiber †	13.16(**)	4.88(**)	21.44(**)	4.67(**)
Rubbed fiber	20.43(**)	3.51(*)	37.36(**)	0.82 (n.s)
Ash †	25.77(**)	5.40(**)	46.13(**)	2.16(n.s)
Pyrophosphate index †	11.21(**)	13.34(**)	9.08(**)	7.85(**)
pH ($CaCl_2$)	0.06(n.s)			0.49(n.s)
Total carbon	4.62(**)	5.82(**)	3.42(*)	1.31(n.s)
Total nitrogen†	3.36(**)	0.01(n.s)	7.30(**)	0.16(n.s)
C:N	8.23(**)	1.16(n.s)	15.31(**)	0.23(n.s)
Exchangeable:				
hydrogen †	0.16(n.s)	0.27(n.s)	0.04(n.s)	3.90(**)
calcium †	28.67(**)	6.25(**)	51.10(**)	0.35(n.s)
magnesium †	14.48(**)	15.51(**)	13.45(**)	0.12(n.s)
aluminum†	2.17(n.s)	0.19(n.s)	4.16(**)	1.09(n.s)
sodium	6.11(**)	11.92(**)	0.30(n.s)	1.10(n.s)
potassium	0.49(n.s)	0.59(n.s)	0.39(n.s)	17.64(**)
CEC †	16.47(**)	2.59(n.s)	30.35(**)	1.10(n.s)
Moss †	58.46(**)	2.39(n.s)	114.54(**)	4.76(**)
Herbaceous	2.70(*)	0.90(n.s)	4.50(**)	0.33(n.s)
Wood	16.87(**)	2.10(n.s)	31.64(**)	10.89(**)
Forest litter †	4.63(**)	1.12(n.s)	8.14(**)	0.32(n.s)
Volume < 0.5 mm †	7.44(**)	1.45(n.s)	13.43(**)	1.12(n.s)
Elevation	46.116(**)	91.73(**)	0.58(n.s)	0.31(n.s)

† transformed values according to Table 3.4
** significant at $P < 0.05$
* significant at $P < 0.10$
n.s not significant

4.2 Prediction of Hydraulic Conductivity

4.2.1 Assessment of Variable Interdependence

4.2.1.1 Correlations

Simple and first order partial correlations were examined to determine which variables are strongly related with K. Correlations among other selected peat properties are also discussed to assess potential difficulties in regression analysis that can arise from use of inter-correlated, explanatory variables.

Table 4.3 presents eight variables significantly correlated ($P < 0.10$) with K. Unrubbed fiber content has the strongest relationship ($r = 0.40$, $P < 0.001$) while bulk density (ash-free) and C:N have the weakest relationships ($r = 0.24$ and 0.24, respectively, $P < 0.08$). Observed correlation coefficients are low and there is not a particularly strong relationship of any of the variables with K. Some relationships have been previously reported; such as K with depth or elevation (Mathur and Levesque 1985), unrubbed fiber content (Nichols and Boelter 1984) and C:N (Levesque et al 1980).

Since elevation defines a spatial position within the peatland and reflects the complex interaction of soil-forming processes at that location, its relationship with K was investigated further to ascertain whether underlying (peat) attributes collectively account for this relationship. First-order partial correlations were performed between elevation and K holding effects of volumetric moisture, unrubbed fiber content, bulk density (ash-free) and C:N constant (Table 4.4). In each case, when the effect of the variable is removed or held constant, there

Table 4.3 Simple product correlations of selected properties with K (n = 56)

Variable	Correlation coefficient (r)	Significance of r
Elevation	0.33	0.01
Moisture content ($m^3\ m^{-3}$)	0.28	0.04
Unrubbed fiber	0.40	0.00
Bulk density (ash free)	-0.24	0.08
Porosity	0.26	0.05
Void ratio	0.29	0.03
Total nitrogen	-0.33	0.01
C:N †	0.24	0.08

† non-transformed

Table 4.4 First-order partial correlations ($P < 0.10$) between elevation and K, controlling for selected peat properties ($n = 56$)

Variable effect controlled	Correlation coefficient (r)	Change in r
None	0.33*	
Moisture content ($m^3\ m^{-3}$)	0.38**	+0.05
Bulk density (ash-free)	0.30*	-0.03
Unrubbed fiber	0.43**	+0.10
C:N †	0.29*	-0.04

* significant at $P < 0.05$
** significant at $P < 0.01$
† non-transformed

is a negligible change in the value of the correlation coefficient and a statistically significant relationship still occurs between elevation and K.

This relationship between K and the position (in the catotelm) of the measurement most likely reflects peat, fluid and/or site attributes that influence K in a linear fashion yet their effect on K is best represented by defining where the peat volume is located in the peatland. Ivanov (1981) states " . . . changes in the coefficient of seepage are due to two main factors - external pressure on the solid matrix, which determines how closely the organic particles of peat and the bound water they contain are compacted, and the quantity of immobilized water in the particles of peat, which determines the size, or (to simplify the physics of the phenomenon) the 'swollenness' of the particles." Subtle changes in the water storage of the peat and in the pressure exerted on the peat matrix are not readily apparent upon examining changes in moisture contents and bulk densities with depth. Although volumetric moisture seems to increase with depth, bulk densities do not appear to exhibit such a trend (Table 4.1). Not only may the position of the peat volume within the catotelm reflect subtle changes in moisture and pressure on the matrix but it may also indicate changes in the degree of decomposition or in floristic composition.

Aside from the significant correlations with K, examination of correlations for 13 other variables indicates that they are, to varying degrees, interrelated (Table 4.5). Moss, wood and ash contents are correlated with the most number of variables while herbaceous content and elevation correlate with the least. Observed correlation

Table 4.5 Simple correlations among selected peat properties (n = 56)

	Elevation	Wood	Herbaceous	Moss	CEC	Exchangeable aluminium	C:N
Moisture ($m^3 m^{-3}$)	-0.52**	-0.34**	0.14	0.29**	0.35**	0.36**	-0.07
Moisture (kg kg^{-1})	-0.09	-0.45**	0.33**	0.61**	0.43**	0.51**	-0.42**
Bulk density	0.11	-0.32**	0.28**	0.48**	0.28**	0.37**	-0.40**
Unrubbed fiber	-0.15	-0.26**	0.10	0.56**	0.14	0.40**	-0.60**
Rubbed fiber	0.23*	-0.46**	0.17	0.67**	0.39**	0.54**	-0.52
Ash	-0.12	-0.61**	0.38**	0.68**	0.62**	0.68**	-0.34**
Pyrophosphate index	0.00	-0.35**	0.17	0.40**	0.40**	0.75**	-0.16
C:N	-0.15	0.10	0.04	-0.40**	0.01	-0.25*	
Exchangeable aluminium	-0.23*	-0.45**	0.10	0.43**	0.37**		
CEC	-0.42**	-0.62**	0.34**	0.50**			
Moss	-0.35**	-0.66**	0.36**				
Herbaceous	-0.16	-0.32*					
Wood	0.36**						

	Pyrophosphate index	Ash	Rubbed fiber	Unrubbed fiber	Bulk density	Moisture (kg kg^{-1})
Moisture ($m^3 m^{-3}$)	0.19	0.18	0.44**	0.50**	-0.08	0.27**
Moisture (kg kg^{-1})	0.56**	0.68**	0.63**	0.58**	0.93**	
Bulk density	0.50**	0.61**	0.48**	0.42**		
Unrubbed fiber	0.28**	0.36**	0.76**			
Rubbed fiber	0.51**	0.60**				
Ash	0.73**					

* significant at $P < 0.10$
** significant at $P < 0.05$

coefficients are generally low; however, there are a few strong relationships such as between moisture content (kg kg^{-1}) and bulk density ($r = 0.93$, $P < 0.001$), rubbed and unrubbed fiber contents ($r = 0.76$, $P < 0.001$) or between pyrophosphate index and exchangeable aluminum ($r = 0.75$, $P < 0.001$). Selection of variables to be used in regression analysis becomes difficult since it is hard to determine the redundancy of each variable's contribution to the variance of K. This problem will be considered in the following section.

4.2.1.2 Principal Components Analysis

Principal Components Analysis (PCA) was used to assess associations among variables and to provide guidelines for selection of independent variables to be used in predicting K. Only 50 cases were included in PCA. Deletion of 6 atypical observations (depth class one) was based on: their higher levels of ash, exchangeable aluminum and pyrophosphate index values (Table 4.1); and, their geographic location. Three locations were at the eastern margin of the study site in the vicinity of the Saulteaux River and three occurred at the western margin in close proximity to upland (mineral) soil.

Using criteria mentioned previously (section 3.4.3.3), four components accomodating 74% of the variation within the data were retained (Table 4.6). The first component accounts for 32% of total variance and represents degree of decomposition in the peat. Variables that have high loadings or relate strongly to this component are: moss, ash, rubbed fiber, wood, CEC and exchangeable aluminum. Except for wood

Table 4.6 Principal components analysis: distribution of variance and variable loadings for retained components

Variable†	Variable loadings on components			
	1	2	3	4
Moss	0.86	-0.11	0.09	-0.22
Ash	0.83	0.11	-0.39	-0.03
Rubbed fiber	0.77	0.07	0.34	0.15
Wood	-0.73	0.44	0.12	0.02
CEC	0.65	-0.38	-0.25	-0.15
Exchangeable aluminum	0.59	0.04	-0.31	0.58
Elevation††	-0.21	0.78	-0.21	0.03
Hydraulic conductivity	0.12	0.68	0.28	-0.12
Bulk density (ash-free)	-0.42	-0.61	0.07	0.43
C:N††	0.45	0.46	0.41	0.04
Unrubbed fiber	0.60	0.23	0.68	0.06
Moisture ($m^3\ m^{-3}$)	0.15	-0.61	0.59	0.24
Pyrophosphate index	0.51	0.29	-0.61	0.34
Herbaceous	0.26	-0.31	0.18	-0.69
eigenvalue	4.5	2.6	2.0	1.3
% of total variance	32	18	14	10
cumulative variance accounted for	32	50	64	74

† variables transformed according to Table 3.4
††non-transformed values

and moss content, these peat characteristics have been previously documented as characterizing degree of decomposition: ash content (Brown and Farnham 1976), rubbed fiber content (Nichols and Boelter 1984, McDonnell and Farrell 1984), CEC (Levesque et al 1980) and exchangeable aluminum (P'yavchenko and Kornilova 1978).

Based on the author's review of the literature, there were no documented instances supporting the use of wood and moss contents to describe the degree of decomposition in peat. One possible explanation for the high negative loading of wood content relates to the relative resistance of wood to decomposition. Heikurainen and Huckari (1952) estimated C:N ratios for woody species found in peat to range between 35 and 45. They attributed wood's relative resistance to decomposition to its high content of lignaceous material. Similarly, for moss content, its high positive loading may also relate to its degradability with respect to other botanical constituents in peat. During microscopic determination of botanical components, the majority of moss enumerated was from the family Amblystegiaceae (Crum 1976) represented by Drepanocladus and Scorpidium spp. Heikurainen and Huckari(1952) estimate the C:N ratio for peat dominantly composed of these mosses as being near 30. Compared to estimated C:N ratios between 40 and 60 for some species of Sphagnum moss (Heikurainen and Huckari 1952), the majority of moss in the samples examined would be expected to degrade more readily. Since Sphagnum moss was not quantitatively estimated its relationship to degree of peat decomposition could not be inferred.

The second component accounts for 18% of the total variation and supports the hypothesis that conductivity decreases with depth because

of the weight of the overlying peat. Variables with high positive loadings are elevation and K while bulk density (ash-free) has the highest negative loading (Table 4.6). In other words, as elevation increases, K increases while bulk density (ash-free) decreases; as elevation and K decrease, bulk density (ash-free) increases. Both Päivanen (1973) and Mathur and Levesque (1985) found that K decreased with depth irrespective of changes in bulk density. They did not, however, correct bulk density values for any increases in ash content that may have occurred. Use of bulk density values that were not corrected to an ash-free basis did not result in a high loading on this component.

The third component accounts for 14% of the total variation and reflects differences in fiber size and moisture resulting partly from decomposition. Pyrophosphate index has the highest negative loading (Table 4.6) and is used to indicate the degree of decomposition in peat (Schnitzer and Desjardins 1965). Both variables that have the highest positive loadings, unrubbed fiber content and volumetric moisture content, are correlated with each other (Table 4.5) and increase with depth (Figure 4.3). During description and classification of peat stratigraphy, an abrupt discontinuity characterized by less decomposed, herbaceous-moss peat was observed within the vicinity of the 2 m depth in 77% (43) of the locations sampled (Appendix 7.1). Although this pattern appeared to be consistent in the vertical dimension, patterns across the study area at each depth were not identified for volumetric moisture content. Linear trends in unrubbed fiber content at 1 and 2 m depths will be discussed in the following section.

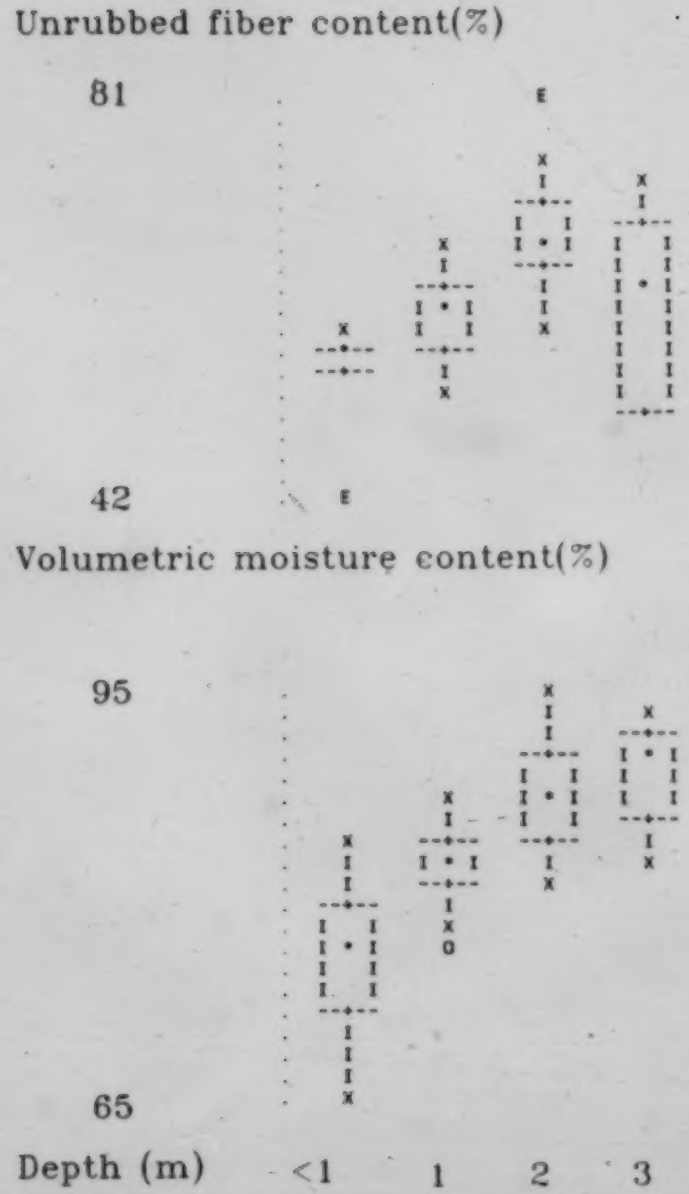


Figure 4.3 Boxplots of unrubbed fiber and volumetric moisture contents with depth. * batch median, x observations < 1 interquartile, o observations between 1 and 1.5 interquartile, E observations > 1.5 interquartile. Box length is one interquartile.

The fourth component accounts for 10% of the total variation and represents the dominant (herbaceous) constituent in the peat (Table 4.6). Interpretation of this component is difficult because the high negative loading of herbaceous content cannot be physiochemically related to a variable with a high positive loading. Variables with high positive loadings on this component have already been allocated to previously discussed components.

To briefly summarize, four components have been retained that account for 74% of the total variation within the data. They have been interpreted as representing degree of decomposition, the decrease in K with depth, differences in fiber size and moisture content resulting from decomposition and the dominant herbaceous content of the peat. The decomposition component accounts for almost one half (43%) of the variation allocated to the four components. Variables closely related (high loading) to this component are not directly correlated with K and may not account for a large portion of the variation in K.

4.2.2 Regression Analysis

Based on results obtained from PCA and using criteria outlined in Section 3.4.3.4, 12 variables were selected for regression analysis. From Table 4.6, these are: moss, ash, rubbed fiber, wood, CEC, elevation, bulk density (ash-free), unrubbed fiber, volumetric moisture, pyrophosphate index and herbaceous content. Ash content was not included on the basis of its high degree of correlation with other selected variables (Table 4.5). Instead, forest litter was added to the subset of variables because, conceptually, its occurrence influences the structure of the peat matrix in a similar capacity as wood.

The formulated model explains fifty eight percent of the variation in K ($P < 0.001$) and has the form,

$$\log_{10}K = -10.3 + 0.3E + 0.06URF^{0.5} - 0.04\sin^{-1}(FL/100)^{0.5} + 0.2W^{0.5} + 263.6CEC^{-1} - 0.02RF$$

where E is the elevation (m) of the in-situ K measurement, URF is unrubbed fiber content (%), FL is forest litter content (%), W is wood content (%), CEC is cation exchange capacity ($cmol(1/2Ba^{++})kg^{-1}$), and RF is rubbed fiber content (%). Elevation and unrubbed fiber content account for approximately one-third (37%) of the total variation in K while the remaining 21% is split more or less equally among the remaining variables (Fig. 4.4). To avoid confusion, defining the position of each in-situ K measurement as a distance above mean sea level only reflects use of an arbitrary datum. Use of this datum does not assign importance to a watershed's location above mean sea level but only serves to quantify the position of the in-situ K measurements within the peat mass. Application of this model to peatlands outside the study site should accomodate this artifact of model design.

Variables in the equation indicate that the elevation at which the measurement was taken, the (unrubbed) fiber content, the amount of woody detritus and the degree of decomposition of the peat influence K. Within the catotelm, the nature of peat at that location arises from the type of plant remains originally deposited, the modifying effects of decomposition, and overburden pressure. From a previous section (Section 4.2.1.2), an association was established among elevation, the magnitude of K and bulk density (ash-free). However, bulk density (ash-free) was not selected during computation of the equation. The

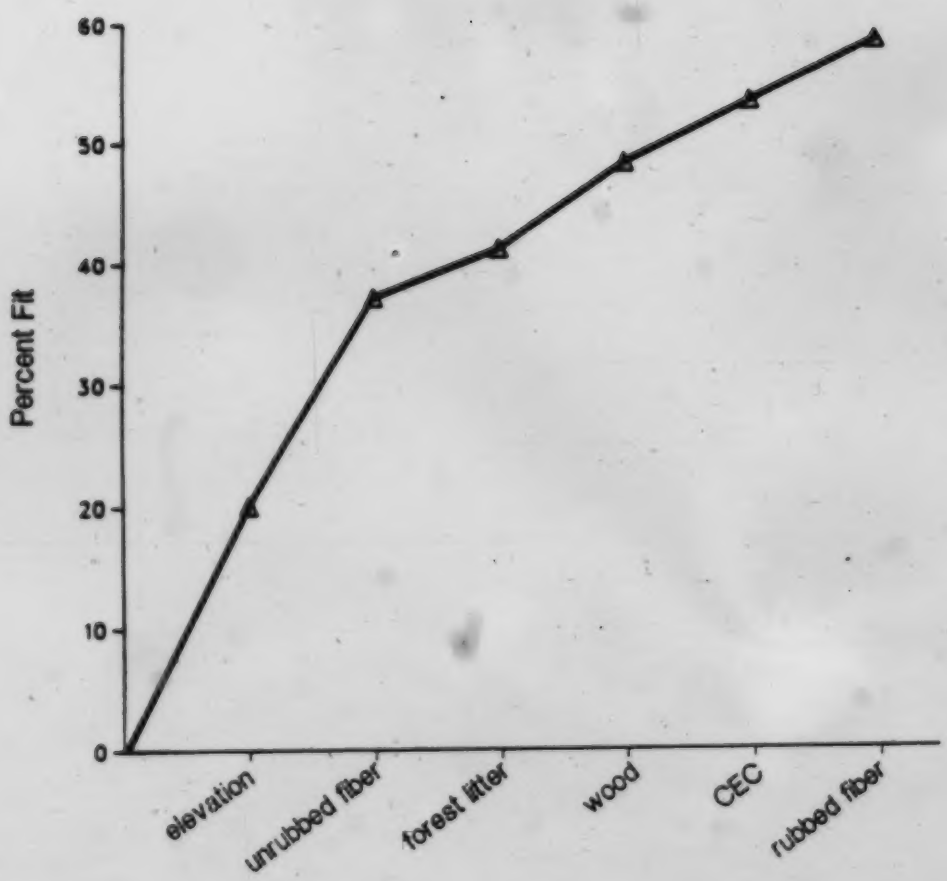


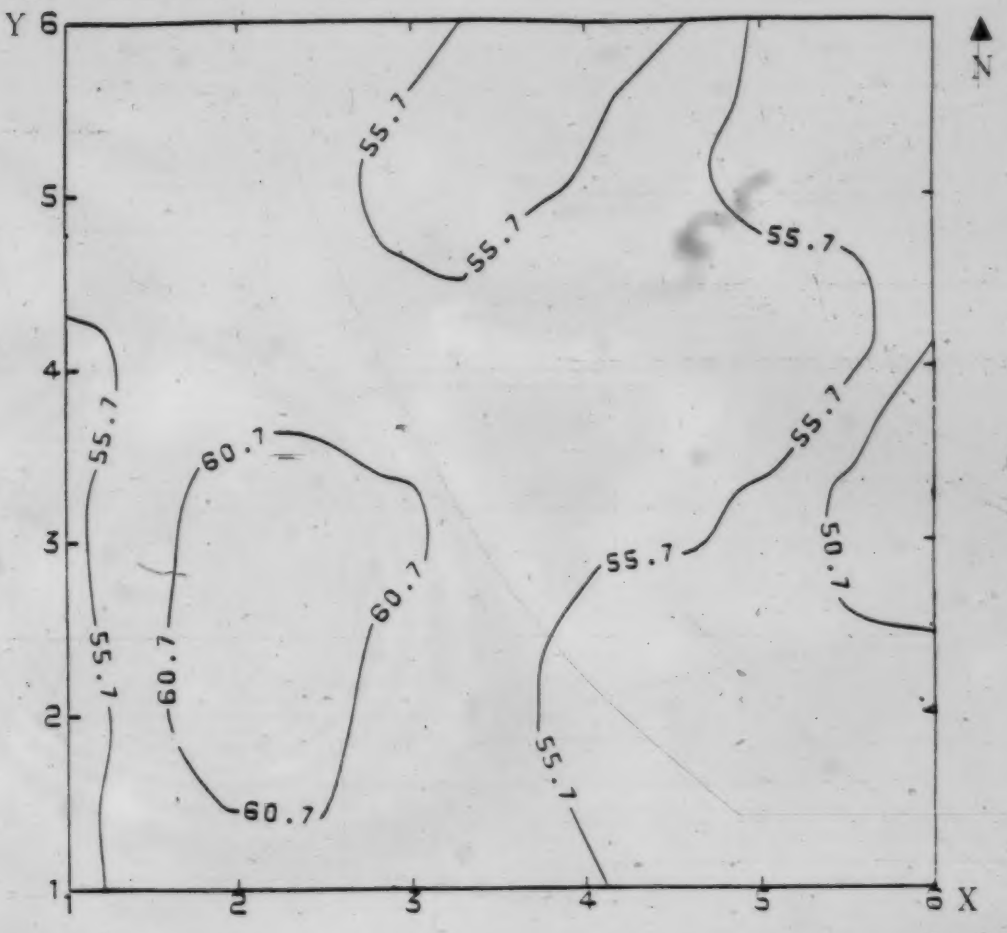
Figure 4.4 Percent fit explained by variables in the model

position within the catotelm and its relationship to K represents more than quantification of external pressure; it also reflects the interaction of other factors controlling peat accumulation and peatland formation. Collectively, they may best be related to K through the elevation (or the position within the catotelm) at which K was determined.

The relationship of unrubbed fiber content to K is analogous to the relationship of soil texture to K in mineral soils. Researchers have found that proportions of sand, silt and clay correlate well with certain soil hydraulic properties such as K (Murali et al 1979) and water retention (Puckett et al 1985). Unrubbed fiber content is related to both K (Table 4.3) and moisture content (Table 4.5). Moisture and unrubbed fiber content increase with depth (Figure 4.3) while the latter exhibits a weak linear trend decreasing from the southwest to the northeast at 1 m depth (Figure 4.5). Unrubbed fiber content defines only two fiber sizes - greater than/less than 0.15 mm - which may or may not produce the best relationship with K. As an example, Nichols and Boelter (1984) established that fibers greater than 0.25 mm relate the best to bulk density. Only one other fiber size was determined (less than 0.5 mm) and it was not used in formulating the model. Further investigation is warranted to determine if other particle size fractions correlate more strongly with K.

The occurrence of wood and forest litter result in wider particle size distribution and alterations in structure. At the 2 m depth, both wood and forest litter content decrease across the site from the southwest to the northeast (Figures 4.6, 4.7). At the 1 m depth, a trend

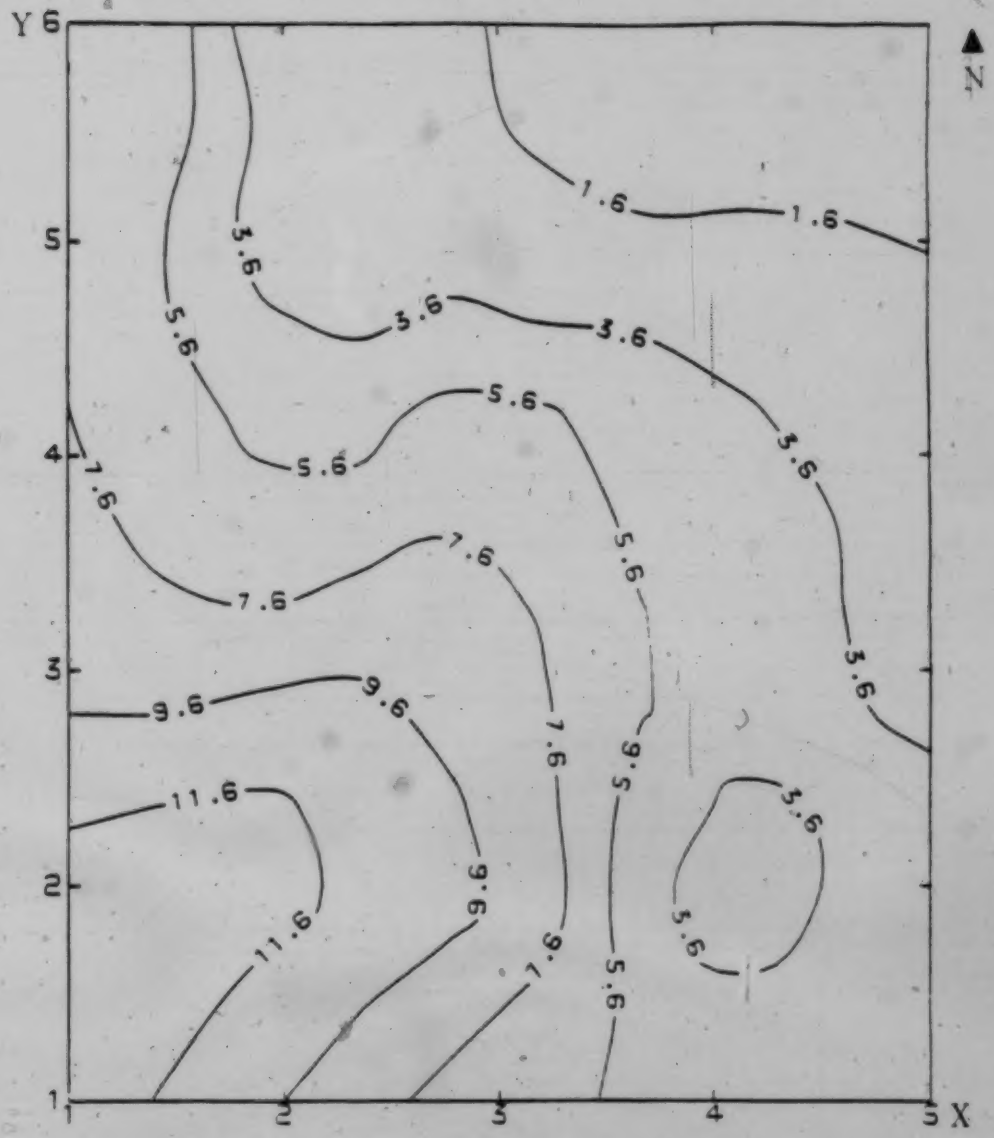
Unrubbed fiber = 59.6 - 1.2X + 0.3Y R^2=0.21
(%) P<0.05



Scale 1:8000 Contour Interval 5.0

Figure 4.5 Linear change in unrubbed fiber content at 1 m depth across the study site.

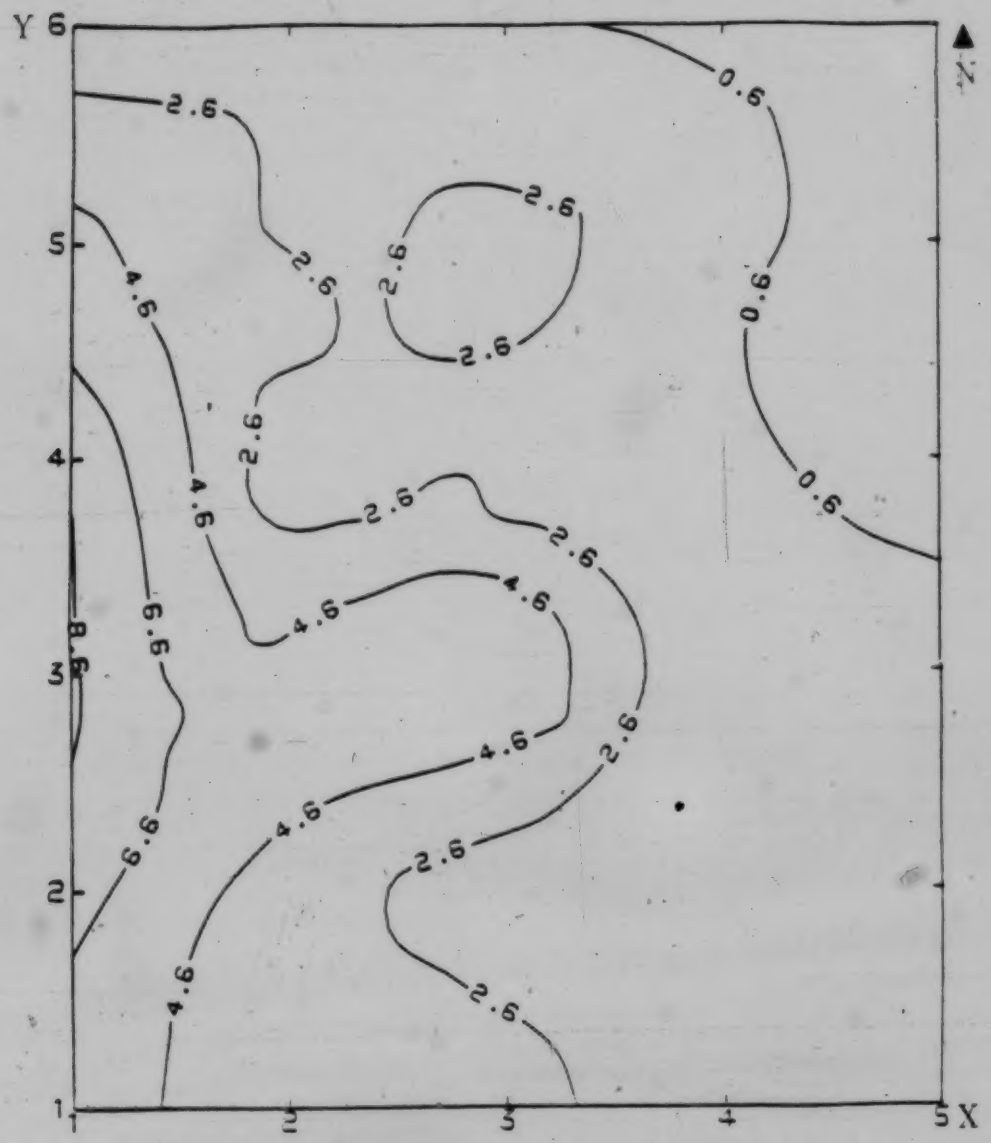
Wood = 14.3 - 1.8X - 1.0Y R^2=0.47
(%) P<0.01



Scale 1:8000 Contour Interval 2.0

Figure 4.6 Linear change in wood content at 2m depth across the study site.

Forest litter = 8.2 - 1.3X - 0.5Y R^2=0.41
(%) P<0.05



Scale 1:8000 Contour Interval 2.0

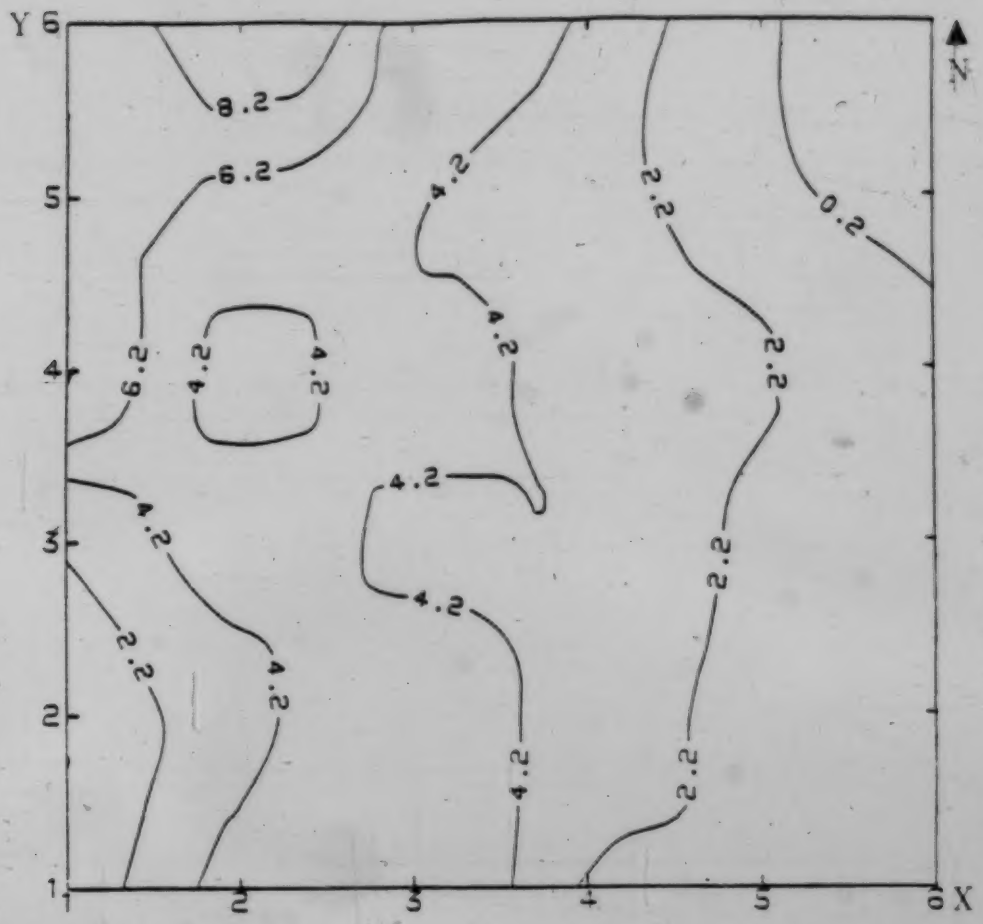
Figure 4.7 Linear change in forest litter content at 2m depth across the study site.

decreasing from west to east occurs for forest litter content (Figure 4.8). Observations made during description and classification of each pedon indicate that wood and forest litter prevents a compact, laminar structure from forming that is characteristic of peat dominantly composed of sedges and graminoids. The effect on K influences the degree of anisotropy in the matrix similar to the effect macropores have on flow in mineral soils; that is, where the incidence of voids and cracks, especially in fine textured horizons, relate to K better than soil texture (McKeague et al 1982).

The remaining two variables CEC and rubbed fiber content have been used to indicate decomposition status in peat (Levesque et al 1980, Lynn et al 1974). Whereas most previous trends at 1 and 2 m depths were decreasing from the southwest to the northeast, minimum values of CEC at 1 m depth occur in the middle of the study site (Figure 4.9). At 2 m depth, CEC decreases from southwest to northeast (Figure 4.10). Rubbed fiber content does not exhibit significant ($P < 0.05$) linear trends at either 1 or 2 m depths.

To briefly reiterate, a first order function explaining 58% of the variation in K has been formulated using the variables, elevation (of the observation above the arbitrary datum), unrubbed fiber, wood, forest litter, CEC and rubbed fiber. Except for elevation, all variables describe certain characteristics of the peat: unrubbed fiber content defines two particle sizes that relate to K (greater than and less than 0.15 mm); wood and forest litter influence K by creating wider particle size distribution and influencing structure; and, CEC and rubbed fiber content indicate chemical and physical differences brought about by

Forest litter = 3.9 − 0.6X + 0.6Y R^2=0.40
(%) P<0.001

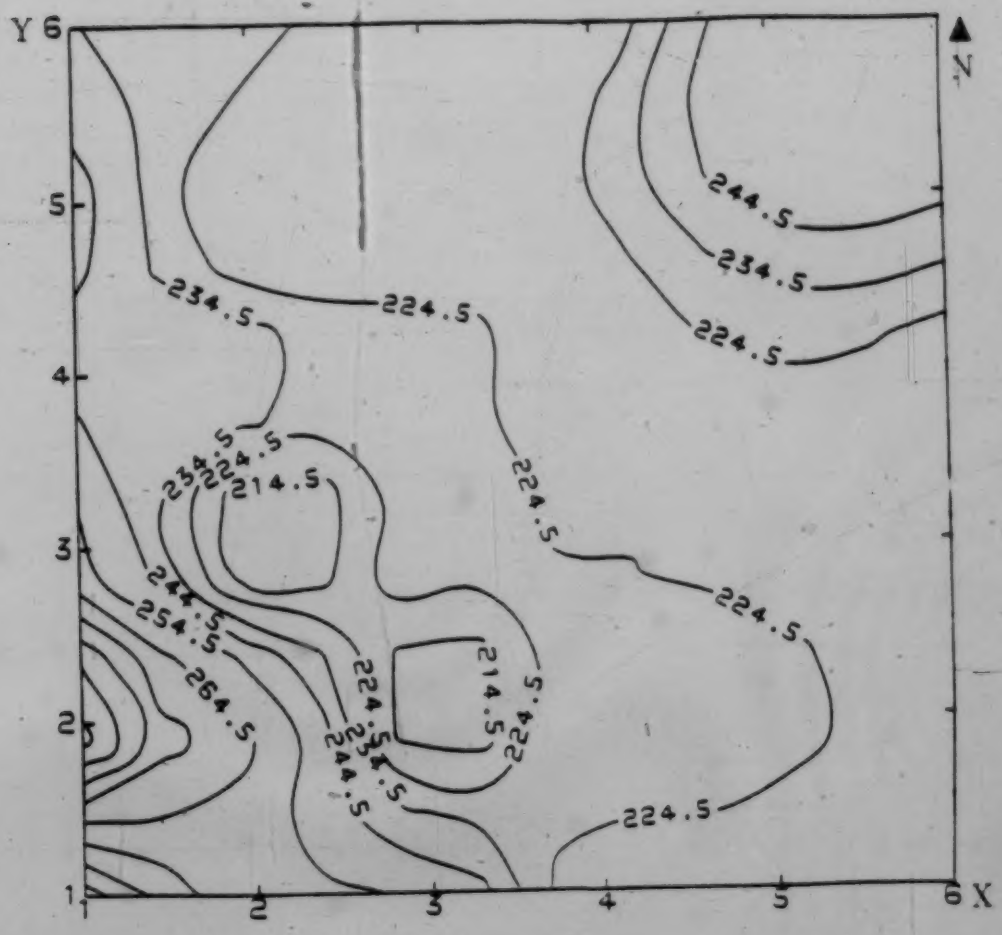


Scale 1:8000 Contour Interval 2.0

Figure 4.8 Linear change in forest litter content at 1 m depth across the study site

CEC = 268.0 - 7.8X - 3.8Y R^2=0.34

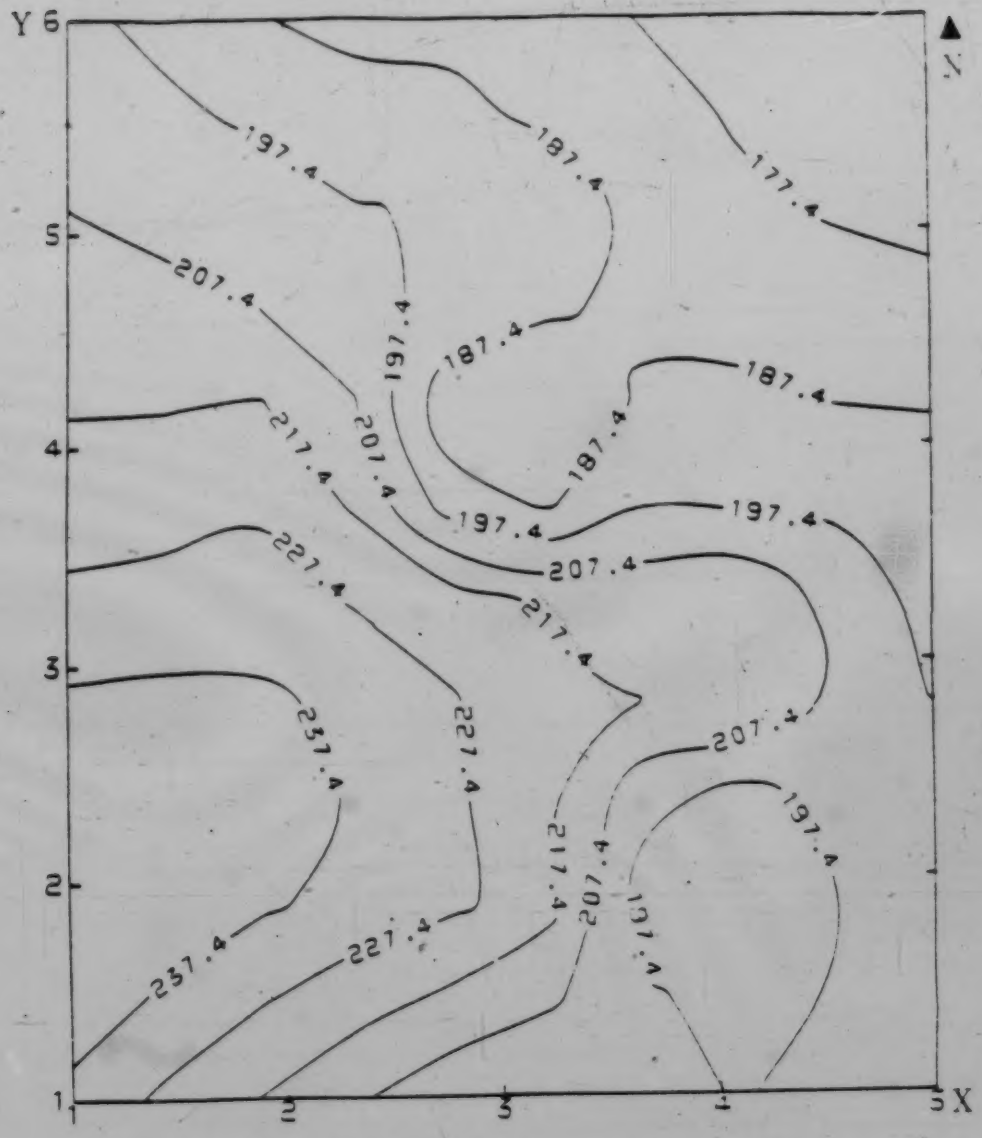
($cmol(1/2Ba^{++})kg^{-1}$) P<0.05



Scale 1:8000 Contour Interval 10.0

Figure 4.9 Linear change in cation exchange capacity at 1 m depth across the study site

CEC = 241.1 - 6.6X - 5.3Y R^2=0.26
($cmol(1/2Ba^{++})kg^{-1}$) P<0.10



Scale 1:8000 Contour Interval 10.0

Figure 4.10 Linear change in cation exchange capacity at 2 m depth across the study site.

decomposition and their effect on K. Three of five variables describing physical, chemical and botanical aspects of the peat exhibit linear trends from southwest decreasing to northeast at 1 and 2 m depths. Only CEC at 1 m depth has a different pattern; minimum values occur in the middle of the study site and values increase southwest and northeast.

4.2.3 Residual Analysis

Analysis of differences between predicted and observed values (residuals) was performed to validate assumptions associated with multiple linear regression (see Section 3.4.3.4). Table 4.7 presents the range and average of predicted and residual values. The equation predicting K underestimated actual values.

Examination of a histogram of standardized residuals, a normal probability plot and a standardized scatterplot of predicted and residual values confirm that the error is homogenous, independent and distributed normally (Figures 4.11, 4.12). Slight peakedness (leptokurtosis) is evident in the histogram of standardized residuals and the normal probability plot. Standardized scatterplots of predicted versus residual values (Figure 4.12) and of individual variables versus residual values indicate plotted points are randomly scattered with the majority falling within one standard deviation of the mean. Aside from 6 atypical observations taken from depths less than 1 m, there is one outlier three standard deviations from the mean.

Examination of standardized partial regression plots for variables in the equation reveal that certain variables relate to K in a nonlinear fashion. The linear model adequately describes the relationship of

Table 4.7 Prediction of K at 1, 2 and 3 m depths: comparison of predicted and observed values

	Minimum	Maximum	Mean
Predicted values ($x10^{-5}$ m s^{-1})	0.16	4.73	1.12
Observed values ($x10^{-5}$ m s^{-1})	0.13	6.31	1.12
Deviation	0.03	1.58	0

Histogram

```
NExp N      (* = 1 Cases,     . : = Normal Curve)
0   .04    Out
0   .08   3.00
0   .20   2.67
0   .45   2.33
1   .91   2.00 :
2  1.67   1.67 *:
2  2.74   1.33 **.
4  4.03   1.00 ***:
4  5.31    .67 ****.
7  6.26    .33 *****:*
9  6.62    .00 ******:**
7  6.26   -.33 *****:*
3  5.31   -.67 *** .
7  4.03  -1.00 ***:***
3  2.74  -1.33 **:
1  1.67  -1.67 *.
0   .91  -2.00 .
0   .45  -2.33
0   .20  -2.67
0   .08  -3.00
0   .04    Out
```

Normal probability plot

Figure 4.11 Prediction of K at 1, 2, and 3 m depths: histogram and normal probability plot of standardized residual values

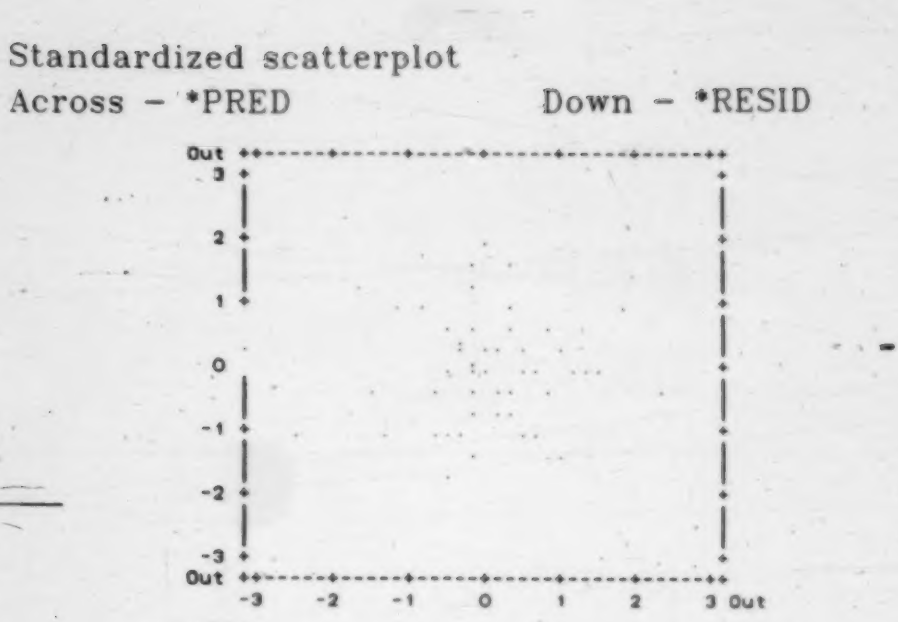


Figure 4.12 Prediction of K at 1, 2, and 3 m depths: scatterplot of standardized predicted(*PRED) and residual(*RESID) values.

elevation, unrubbed fiber, CEC and rubbed fiber with K (Figures 4.13, 4.14). However, for wood and forest litter a nonlinear model may be more suitable (Fig. 4.15). Significant ($P < 0.05$) linear trends across the study site occur for forest litter content at 1 and 2 m depths and for wood content at 2 m depth (Section 4.2.2). The quadratic distribution of wood and forest litter with depth (Table 4.2) is likely responsible for curvilinear patterns appearing on standardized partial regression plots. Addition of second order terms for these variables may improve the fit and applicability of the model in drainage design.

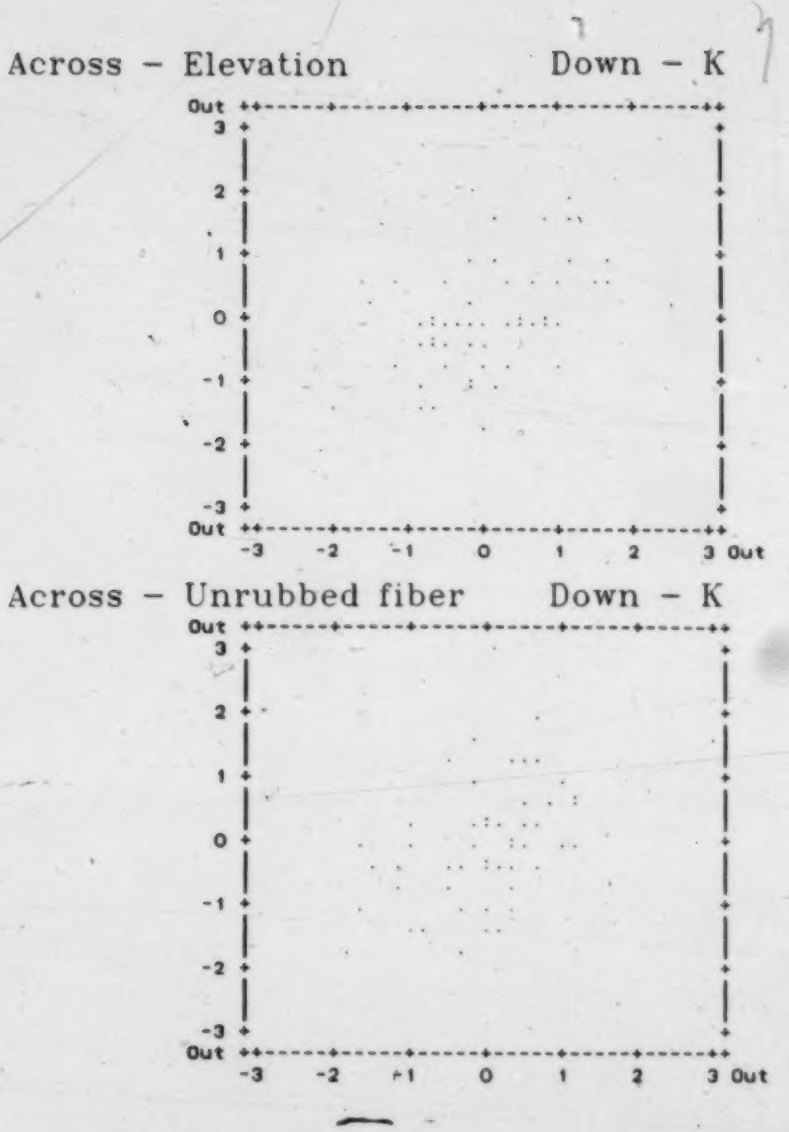


Figure 4.13 Prediction of K at 1, 2, and 3 m depths: standardized partial regression plots for elevation and unrubbed fiber with K.

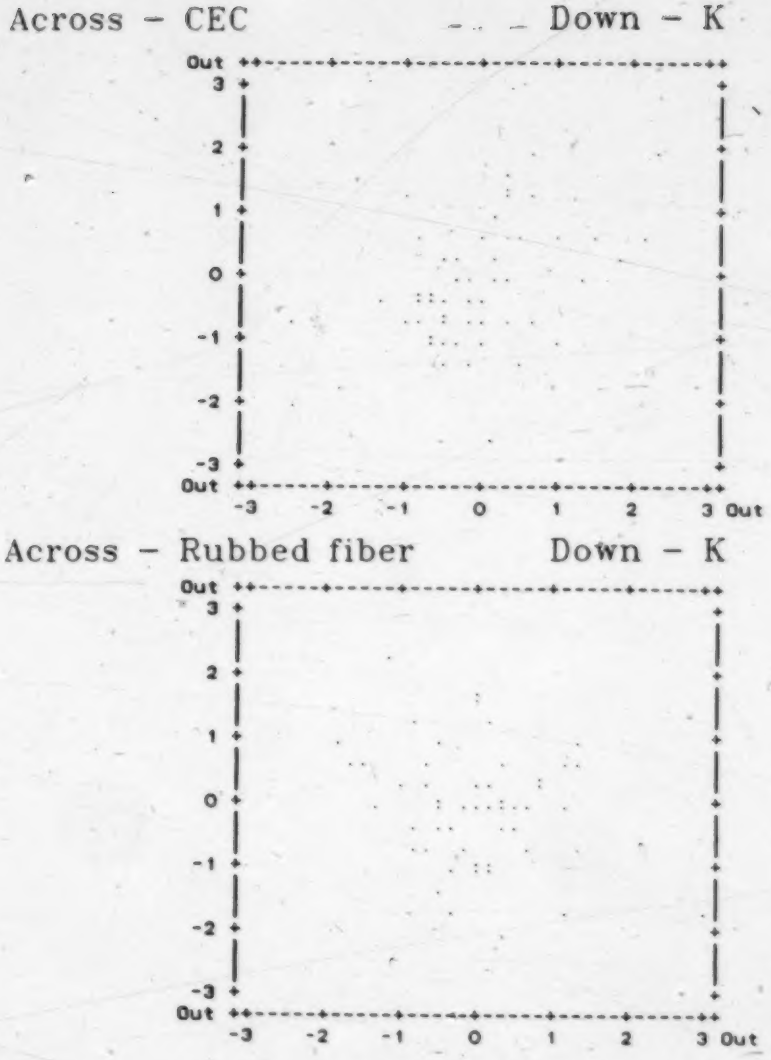


Figure 4.14 Prediction of K at 1, 2, and 3 m depths: standardized partial regression plots for cation exchange capacity(CEC) and rubbed fiber with K.

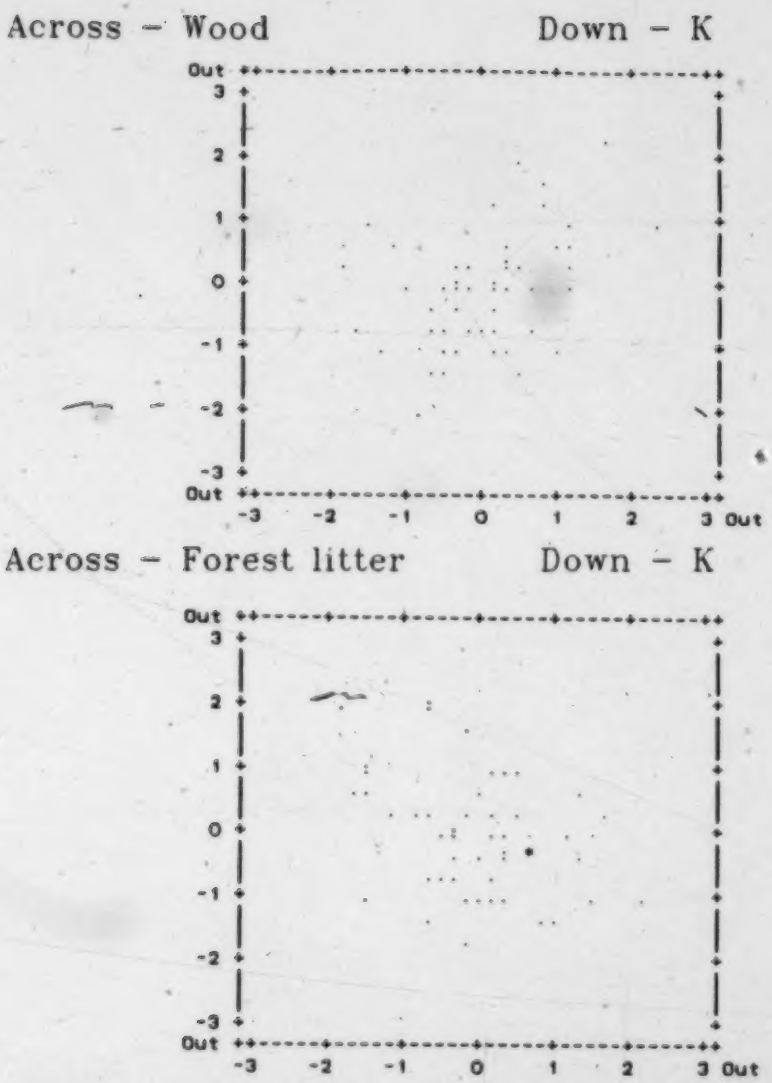


Figure 4.15 Prediction of K at 1, 2, and 3 m depths: standardized partial regression plots for wood and forest litter contents with K.

5.0 Conclusions

The empirical model accounts for 58% of the variation in K ($P < 0.001$) and establishes relationships between K and characteristics of the peat sampled; namely, its degree of decomposition and with factors that influence pore geometry (ie. fiber size distribution, wood content). It has the form,

$$\log_{10}K = -10.3 + 0.3E + 0.6URF^{0.5} - 0.04\sin^{-1}(FL/100)^{0.5} + 0.2W^{0.5} + 263.6CEC^{-1} - 0.02RF$$

where E is the elevation (above an arbitrary datum) of the peat volume sampled, URF is unrubbed fiber content, FL is forest litter content, W is wood content, CEC is cation exchange capacity and RF is rubbed fiber content. Elevation and unrubbed fiber content explain the most variation in K (37%). The remaining (explained) variation (21%) is distributed more or less equally among wood content, forest litter content, CEC and rubbed fiber content.

Reliability and accuracy of the model were not assessed using observations from outside the study site. By using observed K values ranging between 10^{-5} and 10^{-6} m s^{-1}, predicted values of K underestimate actual values. Numerical techniques that allow evaluation of predictive accuracy and reliability (Wegener and Malone 1983) could not be employed because of the unequal number of observations at the various depths.

Not all variables in the model appear linearly related to K; specifically, wood and forest litter contents. Several data transformations were used to improve sample distributions of variables in the model. Whether these transformations represent actual

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Not all variables in the model appear linearly related to K; specifically, wood and forest litter contents. Several data transformations were used to improve sample distributions of variables in the model. Whether these transformations represent actual relationships occurring within the system or if they arise as an artifact of the sample (drawn from the system), remains unanswered.

Several improvements can be made. Application of the model to peatland systems outside of the study area would allow evaluation of predictive reliability, accuracy and would authenticate nonlinear relationships in the model that may reflect those inherent in peatland systems. Secondly, since the value of K is dependent on both fluid and matrix characteristics, inclusion of variables defining attributes of fluid (e.g. temperature) flowing through the peat may result in an improvement in fit. More work is required to confirm these suppositions.

As a final note, quantitative investigation of biological systems requires the researcher to conceptualize the system's operation and surmise methods of measurement. In the absence of existing conceptual frameworks, use of statistical techniques such as principal component analysis can provide a framework. Such a starting point furnishes guidelines to direct future investigations and eventually results in a systematic progression into understanding the system.

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Appendix 7.1

Soil Profile Descriptions and Classification

LEGEND

Structure†				Consistence (Wet)††		Horizon Boundary††			
Kind		Grade				Distinction		Form	
fi	fibered	w	weak	nst	nonsticky	d	diffuse	s	smooth
mt	matted	m	moderate	sst	slightly sticky	g	gradual	w	wavy
l	layered	s	strong	st	sticky	c	clear	i	irregular
gr	granular			vst	very sticky	a	abrupt	b	broken

Composition§		Other§		Root Abundance††	
S	Sphagnum moss	sd	seeds	n	none
B	Brown moss	ch	charcoal	vf	very few
M	Moss	mo	mottles	f	few
C	Sedge	sh	shells	p	plentiful
A	Amorphous			a	abundant
SED	Sedimentary peat				
F	Forest litter, wood				
MIN	Mineral				

† class definitions presented on following page

†† Expert Committee on Soil Survey (1983)

§ Turchenek et al (1984)

Structural Class Definitions

Grade†	Description
weak	indistinct arrangement of structural units; less than 20% of material exhibits aggregation.
moderate	20 to 60% of material exhibits aggregation.
strong	most of the structural units conform to the same arrangement; greater than 60% of the material exhibits aggregation

Kind†	Description
fibered	material in vertical, recumbant or random orientation.
matted	material arranged along horizontal planes with or without compression.
layered	modifier indicating stratification into layers 5 to 10 cm thick.
granular	material spheroidal and characterized by rounded or sub-rounded vertices.
massive	coherent mass; no observable aggregation.

† adapted from Klinka et al (1981)

Sample Location: 11 Terric Fibrisol

Field Description

Horizon	Depth (cm)	Boundary	Colour-Natural	Colour-Pressed	Struc.	Cons.	pH (H_2O)	von Post	Composition (%) S	B	M	C	A	SED	F	MIN	Other	Roots
Of1	0-25	gs	7.5 YR3/2	7.5 YR3/4	w,fi	nst	5.6	3	0	40	0	20	30	0	10	0	-	f
Of2	25-70	cs	10 YR2/2	10 YR3/4	m,fi	nst	6.2	2	0	20	0	60	10	0	10	0	-	a
Om1	70-90	cs	10 YR2/1	7.5 YR3/2	ms	nst	6.2	5	0	0	10	10	70	0	10	0	-	n
Of3	90-125	as	7.5 YR3/2	7.5 YR3/4	w,fi	nst	6.2	3	0	0	20	30	30	0	20	0	-	n
IICg	125-140	-	5 Y4/1	-	ms	st	-	-	0	0	0	0	0	0	0	100	-	n

Sample Location: 12 Terric Mesisol

Field Description

Horizon	Depth (cm)	Boundary	Colour-Natural	Colour-Pressed	Struc.	Cons.	pH (H_2O)	von Post	Composition (%) S	B	M	C	A	SED	F	MIN	Other	Roots
Of	0-20	dw	7.5 YR2/0	10 YR3/3	w,fi	nst	6.2	3	0	0	20	40	30	0	10	0	-	p
Om1	20-55	cs	10 YR2/1	7.5 YR3/4	w,fi	nst	6.2	3	0	0	20	30	30	0	20	0	-	f
Om2	55-97	as	5 YR2.5/1	10 YR2/2	ms	nst	6.2	5	0	0	0	10	70	0	20	0	-	n
IICg	97-105	-	5 Y5/1	-	ms	st	-	-	0	0	0	0	0	0	0	100	-	n

Sample Location: 13 Terric Mesic Humisol

Field Description

Horizon	Depth (cm)	Boundary	Colour-Natural	Colour-Pressed	Struc.	Cons.	pH (H_2O)	von Post	Composition (%) S	B	H	C	A	SED	F	MIN	Other	Roots
Of	0-30	cs	10 YR2/1	10 YR2/2	w,mt	nst	5.6	2	40	0	0	10	20	0	30	0	-	p
Om	30-60	cs	10 YR2/1	7.5 YR3/4	w,mt	nst	5.9	3	0	0	10	10	40	0	40	0	-	vf
Oh	60-90	as	5 YR2.5/1	5 YR2.5/1	ms	sst	6.2	6	0	0	0	10	80	0	10	0	-	n
IICg	90-105	-	5 Y4/1	-	ms	vst	-	-	0	0	0	0	0	0	0	100	-	n

Sample Location: 14 Typic Fibrisol

Field Description

Horizon	Depth (cm)	Boundary	Colour-Natural	Colour-Pressed	Struc.	Cons.	pH (H_2O)	von Post	Composition (%) S	B	H	C	A	SED	F	MIN	Other	Roots
Of1	0-30	gs	7.5 YR3/2	7.5 YR3/4	w,fi	nst	5.7	2	0	20	0	30	20	0	30	0	ch	a
Of2	30-90	gs	7.5 YR3/2	10 YR6/6	m,fi	nst	5.7	3	0	40	0	20	20	0	20	0	sd	f
Of3	90-185	gs	7.5 YR3/2	5 YR4/6	w,mt	nst	5.6	3	0	50	0	30	10	0	10	0	sd	n
Of4	185-210	cs	7.5 YR4/6	7.5 YR5/8	w,mt	nst	5.3	3	0	50	0	30	10	0	10	0	-	n
Om1	210-240	cs	7.5 YR3/2	7.5 YR3/4	w,fi	nst	5.9	4	0	20	0	10	30	0	40	0	sd	n
Om2	240-270	gs	7.5 YR3/2	7.5 YR3/4	ms	sst	6.2	4	0	10	10	10	50	0	20	0	sd	n
Om3	270-370	cs	10 YR2/1	10 YR2/2	m,mt	nst	6.3	4	0	0	10	30	50	0	10	0	-	n
Om4	370-420	cs	10 YR2/1	10 YR3/2	w,mt	sst	6.5	5	0	0	10	10	50	10	10	10	-	n
IIAhb	420-445	cs	10 YR2/2	10 YR2/2	ms	sst	-	-	0	0	0	0	80	0	0	20	-	n
IICg	445-460	-	5 Y4/1	-	ms	st	-	-	0	0	0	0	0	0	0	100	-	n

Sample Location: 15 Typic Fibrisol

Field Description

Horizon	Depth (cm)	Boundary	Colour-Natural	Colour-Pressed	Struc.	Cons.	pH (H_2O)	von Post	Composition (%) S	B	H	C	A	SED	F	MIN	Other	Roots
Of1	0-20	cs	7.5 YR2/0	7.5 YR4/6	m,fi	nst	5.3	2	0	40	0	20	10	0	30	0	-	a
Of2	20-70	cs	7.5 YR3/2	7.5 YR3/4	m,fi	nst	5.6	3	0	50	0	20	20	0	10	0	-	f
Of3	70-90	cs	5 YR3/2	5 YR4/6	m,fi	nst	5.9	3	0	50	0	20	20	0	10	0	-	vf
Of4	90-185	as	7.5 YR3/2	7.5 YR3/4	w,fi	nst	5.9	3	0	40	0	20	20	0	20	0	-	n
Of5	185-210	cs	7.5 YR3/4	10 YR5/6	m,mt	nst	6.2	3	0	30	0	30	30	0	10	0	-	n
Om1	210-245	cs	5 YR2.5/2	5 YR3/4	w,mt	nst	6.2	4	0	0	10	20	50	0	20	0	-	n
Om2	245-275	gs	5 YR2.5/1	5 YR3/4	w,mt	nst	6.2	3	0	0	10	10	40	0	40	0	-	n
Om3	275-325	cs	7.5 YR3/4	10 YR3/3	m,mt	nst	6.2	4	0	0	10	30	40	0	10	0	-	n
Om4	325-375	as	7.5 YR2/0	10 YR2/2	ms	sst	6.4	4	0	0	10	10	60	0	20	0	-	n
IICg	375-385	-	5 Y4/1	-	ms	vst	-	-	0	0	0	0	0	0	0	100	-	n

Sample Location: 16 Terric Fibrisol

Field Description

Horizon	Depth (cm)	Boundary	Colour-Natural	Colour-Pressed	Struc.	Cons.	pH (H_2O)	von Post	Composition (%) S	B	H	C	A	SED	F	MIN	Other	Roots
Of1	0-25	gs	7.5 YR2/0	7.6 YR3/4	w,fi	nst	5.3	2	0	40	0	40	10	0	10	0	sd	a
Of2	25-125	gs	7.5 YR3/2	5 YR4/6	m,fi	nst	5.3	3	0	40	0	20	10	0	30	0	-	vf
Of3	125-190	cs	7.5 YR3/4	10 YR5/6	m,fi	nst	5.9	3	0	40	0	30	20	0	10	0	sd	n
Of4	190-210	gs	7.5 YR4/4	10 YR5/6	m,mt	nst	6.2	4	0	50	0	20	20	0	10	0	sd	n
Om	210-260	gs	5 YR2.5/2	5 YR3/3	ms	nst	6.2	4	0	10	0	10	70	0	10	0	-	n
Oh	260-285	as	10 YR2/1	10 YR2/1	ms	sst	6.2	6	0	0	0	0	90	0	10	0	-	n
IICg	285-290	-	7.5 YR2/0	-	ms	st	-	-	0	0	0	0	0	0	0	100	-	n

Sample Location: 21 Typic Fibrisol

Field Description

Horizon	Depth (cm)	Boundary	Colour-Natural	Colour-Pressed	Struc.	Cons.	pH (H_2O)	von Post	Composition (%) S	B	M	C	A	SED	F	MIN	Other	Roots
Om1	0-35	gs	10 YR2/2	10 YR2/3	w,fi	nst	6.2	4	0	30	0	20	40	0	10	0	-	a
Of1	35-80	cs	7.5 YR3/2	7.5 YR4/4	w,fi	nst	5.9	3	0	0	10	30	20	0	40	0	-	vf
Om2	80-100	cs	10 YR2/1	10 YR2/2	ms	sst	6.2	5	0	0	0	10	70	0	20	0	-	vf
Of2	100-120	gs	7.5 YR3/2	7.5 YR4/4	w,fi	nst	6.2	3	0	0	10	20	20	0	50	0	-	n
Of3	120-205	cs	7.5 YR3/4	7.5 YR5/4	w,mt	nst	6.2	3	40	0	0	20	20	0	20	0	-	n
Of4	205-225	cs	7.5 YR3/4	7.5 YR5/6	m,fi	nst	6.2	3	0	40	0	20	20	0	20	0	-	n
Om3	225-235	as	7.5 YR3/2	7.5 YR3/4	w,fi	nst	6.2	4	0	20	0	10	40	0	30	0	-	n
IICg	235-250	-	5 Y5/1	-	ms	st	-	-	0	0	0	0	0	0	0	100	-	n

Sample Location: 22 Mesic Fibrisol

Field Description

Horizon	Depth (cm)	Boundary	Colour-Natural	Colour-Pressed	Struc.	Cons.	pH (H_2O)	von Post	Composition (%) S	B	M	C	A	SED	F	MIN	Other	Roots
Om1	0-35	gs	7.5 YR3/1	7.5 YR3/2	w,fi	nst	6.2	3	0	20	0	10	40	0	30	0	-	a
Of1	35-80	as	7.5 YR4/4	7.5 YR5/6	m,fi	nst	6.2	3	0	60	0	20	10	0	10	0	-	vf
Om2	80-120	cs	7.5 YR3/1	7.5 YR3/2	w,fi	nst	6.2	3	0	0	20	20	30	0	30	0	-	vf
Of2	120-175	as	7.5 YR3/4	10 YR6/4	m,fi	nst	6.2	3	0	70	0	10	10	0	10	0	-	n
Om3	175-185	cs	10 YR2/1	10 YR2/2	ms	nst	6.5	4	0	0	10	10	70	0	10	0	-	n
IICg	185-220	-	5 Y5/1	-	ms	st	-	-	0	0	0	0	0	0	0	100	-	n

Sample Location: 23 Fibric Mesisol

Field Description

Horizon	Depth (cm)	Boundary	Colour-Natural	Colour-Pressed	Struc.	Cons.	pH (H_2O)	von Post	Composition (%) S	B	M	C	A	SED	F	MIN	Other	Roots
Of1	0-20	cs	7.5 YR6/5	7.5 YR8/4	s,fi	nst	5.0	1	90	0	0	0	0	0	10	0	-	f
Of2	20-85	cs	7.5 YR3/2	7.5 YR4/6	w,fi	nst	5.7	2	40	0	0	30	20	0	10	0	sd	vf
Om1	85-150	gs	7.5 YR3/2	7.5 YR4/4	w,fi	nst	5.9	4	0	0	20	20	40	0	20	0	sd	vf
Of3	150-175	cs	7.5 YR3/3	7.5 YR4/4	m,mt	nst	6.2	3	0	0	10	70	20	0	0	0	-	vf
Om2	175-195	as	7.5 YR2/2	7.5 YR2/3	w,mt	nst	6.2	4	0	0	10	20	50	0	20	0	-	n
IICg	195-215	-	5 Y4/0	-	ms	vst	-	-	0	0	0	0	0	0	0	100	-	n

Sample Location: 24 Mesic Fibrisol

Field Description

Horizon	Depth (cm)	Boundary	Colour-Natural	Colour-Pressed	Struc.	Cons.	pH (H_2O)	von Post	Composition (%) S	B	M	C	A	SED	F	MIN	Other	Roots
Of1	0-25	gs	7.5 YR3/2	7.5 YR4/6	m,fi	nst	5.9	2	0	10	0	40	20	0	30	0	sd	n
Om1	25-70	gs	7.5 YR3/2	7.5 YR4/4	m,fi	nst	5.9	3	0	20	0	20	30	0	30	0	sd	f
Of2	70-130	cs	7.5 YR3/2	7.5 YR4/6	m,fi	nst	5.9	3	0	30	0	20	20	0	30	0	-	vf
Om2	130-175	gs	7.5 YR3/2	7.5 YR3/4	w,mt	nst	5.9	4	0	20	0	20	40	0	20	0	sd	n
Of3	175-210	cs	10 YR4/4	10 YR4/6	m,mt	nst	5.9	2	0	30	0	70	0	0	0	0	-	n
Om3	210-240	cs	7.5 YR3/2	7.5 YR3/4	m,mt	nst	6.0	2	0	0	10	20	30	0	40	0	-	n
Om4	240-250	*	7.5 YR3/2	7.5 YR3/4	m,mt	nst	6.2	5	0	0	10	10	60	0	20	0	-	n
*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

* Profile description incomplete (sampler lost).

Sample Location: 25 Fibric Mesisol

Field Description

Horizon	Depth (cm)	Boundary	Colour-Natural	Colour-Pressed	Struc.	Cons.	pH (H_2O)	von Post	Composition (%) S	B	M	C	A	SED	F	MIN	Other	Roots
Om1	0-25	gs	5 YR2.5/1	7.5 YR3/4	w,fi	nst	5.6	3	0	30	0	10	40	0	20	0	sd	a
Of1	25-70	cs	7.5 YR3/2	7.5 YR4/4	m,fi	nst	5.9	2	0	20	0	30	30	0	20	0	sd	f
Om2	70-110	cs	7.5 YR3/2	7.5 YR4/4	w,fi	nst	5.9	3	0	0	20	20	40	0	20	0	sd	vf
Om3	110-130	cs	5 YR3/2	5 YR3/3	w,mt	sst	5.9	4	0	20	0	20	50	0	10	0	sd	n
Of2	130-145	cs	7.5 YR3/2	7.5 YR4/6	m,mt	nst	5.9	3	0	30	0	40	20	0	10	0	sd	n
Of3	145-175	cs	7.5 YR3/2	7.5 YR3/4	w,mt	nst	5.9	5	0	20	0	30	30	0	20	0	sd	n
Of4	175-235	gs	7.5 YR3/2	7.5 YR4/4	m,mt	nst	5.9	3	0	40	0	30	20	0	10	0	-	n
Om4	235-290	cs	7.5 YR3/2	7.5 YR3/4	w,mt	sst	5.9	4	0	20	0	30	40	0	10	0	-	n
Om5	290-340	as	10 YR3/2	10 YR3/3	m,mt	sst	6.2	4	0	0	10	30	60	0	0	0	-	n
IICg	340-350	-	10 YR3/1	-	ms	st	-	-	0	0	0	0	0	0	0	100	-	n

Sample Location: 26 Mesic Fibrisol

Field Description

Horizon	Depth (cm)	Boundary	Colour-Natural	Colour-Pressed	Struc.	Cons.	pH (H_2O)	von Post	Composition (%) S	B	M	C	A	SED	F	MIN	Other	Roots
Om1	0-25	gs	7.5 YR2/0	2.5 YR3/4	w,fi	nst	5.9	2	0	20	0	10	40	0	30	0	-	a
Of1	25-85	cs	5 YR2.5/2	7.5 YR3/4	m,fi	nst	5.6	3	0	30	0	20	30	0	20	0	-	p
Om2	85-125	cs	10 YR2/2	5 YR4/4	m,fi	nst	5.9	4	0	30	0	20	20	0	30	0	sd	n
Of2	125-170	as	5 YR2.5/2	5 YR4/4	w,mt	nst	6.0	3	0	20	0	20	20	0	40	0	sd	n
Of3	170-240	cs	7.5 YR3/4	7.5 YR4/6	m,mt	nst	5.9	3	0	40	0	40	10	0	10	0	sd	n
Om3	240-290	gs	7.5 YR3/2	10 YR3/3	w,fi	sst	6.2	4	0	30	0	40	30	0	0	0	-	n
Om4	290-325	gs	10 YR2/1	7.5 YR3/4	w,fi	sst	6.5	5	0	0	20	20	50	0	10	0	sd	n
Oh	325-350	as	10 YR3/3	10 YR3/4	ms	sst	6.5	7	0	0	10	10	80	0	0	0	sd	n
IICg	350-360	-	10 YR3/1	-	ms	st	-	-	0	0	0	0	0	0	0	100	-	n

Sample Location: 31 Typic Fibrisol

Field Description

Horizon	Depth (cm)	Boundary	Colour-Natural	Colour-Pressed	Struc.	Cons.	pH (H_2O)	von Post	Composition (%) S	B	M	C	A	SED	F	MIN	Other	Roots
Of1	0-45	gs	10 YRw/2	10 YR3/2	m,fi	nst	5.9	3	0	30	0	30	30	0	10	0	sd	a
Of2	45-75	gs	5 YR2.5/2	5 YR4/6	w,fi	nst	5.9	3	0	30	0	30	30	0	10	0	sd	vf
Of3	75-125	cs	5 YR3/3	7.5 YR4/6	m,fi	nst	6.2	2	0	40	20	20	10	0	10	0	-	n
Of4	125-170	cs	5 YR3/3	7.5 YR4/6	w,mt	nst	6.2	2	0	60	10	10	10	0	10	0	sd	n
Of5	170-220	as	5 YR3/4	7.5 YR4/6	w,mt	nst	6.2	3	0	30	10	30	20	0	10	0	ch	n
Om1	220-240	as	7.5 YR3/4	7.5 YR4/6	m,mt	sst	6.2	4	0	0	30	40	30	0	0	0	-	n
Om2	240-275	gs	10 YR2/2	10 YR3/2	w,mt	sst	6.3	4	0	0	10	10	60	0	0	0	-	n
Om3	275-305	cs	10 YR2/2	10 YR2/2	m,mt	sst	-	5	0	0	20	10	70	0	0	0	-	n
Oh	305-315	as	10 YR2/2	-	w,mt	sst	-	7	0	0	0	20	80	0	0	0	-	n
IICg	315-350	-	5 GY5/1	-	ms	st	-	-	0	0	0	0	0	0	0	100	-	n

Sample Location: 32 Mesic Fibrisol

Field Description

Horizon	Depth (cm)	Boundary	Colour-Natural	Colour-Pressed	Struc.	Cons.	pH (H_2O)	von Post	Composition (%) S	B	M	C	A	SED	F	MIN	Other	Roots
Om1	0-25	gs	7.5 YR2/0	2.5 YR3/2	w,fi	sst	6.2	3	0	40	0	30	20	0	10	0	ch	a
Of1	25-80	cs	10 YR2/2	10 YR4/4	m,fi	nst	6.2	3	0	30	0	30	20	0	20	0	sd	f
Om2	80-115	gs	10 YR3/2	10 YR5/3	w,fi	sst	6.2	4	0	10	0	20	40	0	30	0	sd,sh	n
Of2	115-160	cs	7.5 YR3/2	2.5 YR3/4	w,mt	nst	5.9	4	0	20	0	30	30	0	10	0	ch,sd	n
Of3	160-220	cs	7.5 YR3/4	10 YR6/6	w,l/fi	nst	5.9	3	10	0	20	30	10	0	30	0	-	n
Oh	220-235	cs	10 YR2/1	10 YR2/1	ms	sst	-	7	0	0	0	0	90	0	10	0	-	n
IICg1	235-240	as	2.5 YR3/0	-	ms	st	-	-	0	0	0	0	0	0	0	100	-	n
IICg2	240-250	-	5 GY5/1	-	ms	st	-	0	0	0	0	0	0	0	0	100	-	n

Sample Location: 33 Typic Fibrisol

Field Description

Horizon	Depth (cm)	Boundary	Colour-Natural	Colour-Pressed	Struc.	Cons.	pH (H_2O)	von Post	Composition (%) S	B	M	C	A	SED	F	MIN	Other	Roots
Of1	0-45	cs	7.5 YR4/4	10 YR7/3	s,fi	nst	5.7	2	80	0	0	20	0	0	0	0	-	p
Of2	45-110	gs	7.5 YR3/2	7.5 YR4/4	w,fi	nst	5.9	3	0	0	20	20	20	0	40	0	-	vf
Of3	110-145	gs	7.5 YR3/2	7.5 YR4/4	w,mt	nst	6.2	3	0	0	20	40	30	0	10	0	-	n
Of4	145-175	gs	7.5 YR3/3	7.5 YR4/4	w,mt	nst	6.2	4	0	0	10	70	20	0	0	0	-	n
Om1	175-235	cs	7.5 YR3/2	7.5 YR3/4	ms	nst	6.2	4	0	0	10	30	40	0	20	0	-	n
Oh	235-245	as	10 YR2/1	10 YR2/2	ms	sst	6.2	7	0	0	0	20	80	0	0	0	-	n
IICg	245-250	-	2.5 YR4/0	-	ms	st	-	-	0	0	0	0	0	0	0	100	-	n

Sample Location: 34 Typic Fibrisol

Field Description

Horizon	Depth (cm)	Boundary	Colour-Natural	Colour-Pressed	Struc.	Cons.	pH (H_2O)	von Post	Composition (%) S	B	M	C	A	SED	F	MIN	Other	Roots
Of1	0-35	as	7.5 YR4/4	10 YR7/5	s,fi	nst	5.5	2	90	0	0	0	0	0	10	0	-	p
Of2	35-105	cs	7.5 YR3/2	7.5 YR5/5	m,fi	nst	5.7	3	50	0	0	30	10	0	10	0	-	vf
Of3	105-150	cs	7.5 YR3/2	7.5 YR3/4	w,fi	nst	5.9	3	0	0	10	50	30	0	10	0	-	n
Of4	150-245	cs	7.5 YR3/2	7.5 YR4/6	m,mt	nst	5.9	3	0	0	10	70	10	0	10	0	-	n
Om	245-260	cs	10 YR3/3	10 YR4/4	s,mt	sst	6.2	4	0	10	0	50	40	0	0	0	-	n
Oh	260-270	as	10 YR2/1	10 YR2/1	ms	sst	6.2	7	0	0	0	20	80	0	0	0	-	n
IICg	270-280	-	2.5 YR4/0	-	ms	st	-	-	0	0	0	0	0	0	0	100	-	n

Sample Location: 35 Typic Fibrisol

Field Description

Horizon	Depth (cm)	Boundary	Colour-Natural	Colour-Pressed	Struc.	Cons.	pH (H_2O)	von Post	Composition (%) S	B	M	C	A	SED	F	MIN	Other	Roots
Of1	0-30	gs	10 YR2/2	10 YR3/4	m,fi	nst	5.9	2	0	30	0	0	30	0	40	0	sd	a
Of2	30-90	gs	10 YR2/2	7.5 YR4/4	w,fi	nst	5.9	3	0	20	0	0	30	0	50	0	-	p
Of3	90-180	gs	10 YR3/3	10 YR4/4	w,l/fi	nst	5.9	2	0	0	0	60	10	0	30	0	sd	n
Of4	180-210	as	10 YR2/1	10 YR2/2	w,mt	nst	6.2	2	0	0	0	40	20	0	40	0	sd	n
Of5	210-230	gs	10 YR2/1	10 YR2/2	m,l/fi	nst	6.5	2	0	0	0	20	20	0	60	0	-	n
Of6	230-340	gs	10 YR2/2	10 YR3/3	w,mt	nst	6.2	3	0	0	0	60	30	0	10	0	sd	n
Om	340-360	cs	10 YR2/1	10 YR2/2	ms	sst	6.5	4	0	0	0	20	60	0	20	0	sd	n
IICg	360-370	-	2.5 Y5/0	-	ms	sst	-	-	0	0	0	0	0	0	0	100	-	n

Sample Location: 36 Typic Fibrisol

Field Description

Horizon	Depth (cm)	Boundary	Colour-Natural	Colour-Pressed	Struc.	Cons.	pH (H_2O)	von Post	Composition (%) S	B	M	C	A	SED	F	MIN	Other	Roots
Of1	0-20	cs	7.5 YR2/0	7.5 YR3/4	m,fi	nst	5.6	2	0	40	0	10	30	0	20	0	-	a
Of2	20-65	cs	5 YR2.5/2	5 YR3/4	m,fi	nst	5.6	3	0	40	0	10	30	0	20	0	sd	p
Of3	65-110	gs	5 YR2.5/2	5 YR3/4	m,fi	nst	5.3	3	0	40	0	30	10	0	20	0	ch	n
Of4	110-160	cs	5 YR2/2	7.5 YR4/6	m,fi	nst	5.3	4	0	40	0	30	10	0	20	0	sd	n
Of5	160-205	cs	10 YR2/2	10 YR3/4	w,fi	nst	5.6	4	0	20	0	60	10	0	10	0	sd	n
Of6	205-255	gs	10 YR2/2	10 YR2/4	w,l	nst	5.6	3	0	20	0	30	20	0	30	0	sd	n
Om	255-340	gs	10 YR2/2	10 YR4/4	w,fi	sst	5.6	4	0	0	20	40	30	0	10	0	-	n
Oh	340-370	gs	10 YR3/1	10 YR2/1	ms	sst	6.2	7	0	0	0	10	80	0	10	0	-	n
Occ	370-400	-	10 YR6/1	-	w,gr	sst	-	-	0	0	0	0	20	80	0	0	sh	n

Sample Location: 42 Mesic Fibrisol

Field Description

Horizon	Depth (cm)	Boundary	Colour-Natural	Colour-Pressed	Struc.	Cons.	pH (H_2O)	von Post	Composition (%) S	B	M	C	A	SED	F	MIN	Other	Roots
Of1	0-20	gs	7.5 YR2/0	7.5 YR3/2	m,fi	nst	6.2	2	0	20	20	10	30	0	20	0	-	a
Of2	20-70	cs	7.5 YR3/2	10 YR3/4	m,fi	nst	5.9	3	0	40	10	20	20	0	10	0	sd	f
Of3	70-100	gs	5 YR3/4	5 YR4/6	m,fi	nst	5.9	4	0	40	0	20	20	0	20	0	sd	n
Om1	100-160	as	5 YR2.5/2	7.5 YR3/6	w,fi	st	5.6	5	0	30	0	10	40	0	20	0	sd	n
Of4	160-210	cs	5 YR4/6	7.5 YR5/8	m,mt	nst	5.6	4	0	50	0	30	10	0	10	0	sd	n
Of5	210-230	gs	7.5 YR3/2	10 YR3/1	w,mt	nst	6.2	4	0	0	20	30	40	0	10	0	-	n
Om2	230-245	cs	10 YR2/2	10 YR2/2	w,mt	sst	-	5	0	0	0	10	80	0	10	0	-	n
Oh	245-260	cs	10 YR2/1	10 YR2/1	as	sst	-	6	0	0	0	0	90	0	10	0	-	n
IICg	260-270	-	5 GY5/1	-	as	-	-	-	0	0	0	0	0	0	0	100	-	n

Sample Location: 43 Fibric Mesisol

Field Description

Horizon	Depth (cm)	Boundary	Colour-Natural	Colour-Pressed	Struc.	Cons.	pH (H_2O)	von Post	Composition (%) S	B	M	C	A	SED	F	MIN	Other	Roots
Of1	0-20	gs	10 YR2/1	10 YR3/6	s,fi	nst	5.9	1	0	20	50	10	10	0	10	0	-	p
Om1	20-85	cs	7.5 YR3/2	7.5 YR4/4	w,fi	sst	5.9	4	0	40	10	10	30	0	10	0	sd	f
Of2	85-120	cs	7.5 YR3/2	7.5 YR3/4	w,fi	nst	5.6	4	0	20	0	10	40	0	30	0	ch	n
Om2	120-140	cs	7.5 YR3/2	5 YR3/4	w,mt	sst	5.6	4	0	40	0	0	40	0	20	0	-	n
Of3	140-210	cs	10 YR4/6	10 YR6/6	w,mt	nst	5.6	3	20	20	10	30	10	0	10	0	-	n
Of4	210-225	cs	5 YR2.5/1	10 YR2/2	w,fi	nst	5.6	4	0	0	20	10	50	0	20	0	-	n
Om3	225-240	cs	10 YR2/2	10 YR3/2	w,mt	nst	5.6	5	0	0	10	10	60	0	20	0	-	n
IICg	240-250	-	5 GY5/1	-	as	sst	-	-	0	0	0	0	0	0	0	100	-	n

Sample Location: 44 Typic Fibrisol

Field Description

Horizon	Depth (cm)	Boundary	Colour-Natural	Colour-Pressed	Struc.	Cons.	pH (H_2O)	von Post	Composition (%) S	B	M	C	A	SED	F	MIN	Other	Roots
Of1	0-30	gs	10 YR2/2	10 YR3/3	m,fi	nst	5.9	2	0	40	0	20	20	0	20	0	-	p
Of2	30-65	cs	10 YR2/2	7.5 YR4/6	w,fi	nst	5.9	3	0	30	10	20	20	0	20	0	sd	vf
Of3	65-115	cs	5 YR2.5/1	7.5 YR3/4	m,fi	nst	5.6	3	0	20	0	30	30	0	20	0	sd	n
Of4	115-165	cs	7.5 YR3/4	10 YR3/4	w,l/mt	nst	5.6	3	0	30	0	30	20	0	20	0	sd	n
Of5	165-205	cs	7.5 YR3/4	10 YR4/6	w,mt	nst	5.6	3	30	30	10	20	10	0	0	0	-	n
Om1	205-215	cs	10 YR2/1	10 YR2/2	w,fi	sst	5.6	4	0	0	20	20	50	0	10	0	sd	n
Om2	215-230	as	5 YR2.5/1	5 YR3/4	w,mt	sst	6.2	4	0	0	30	20	40	0	10	0	-	n
Of6	230-240	cs	7.5 YR3/4	10 YR4/4	w,mt	nst	6.2	3	0	0	20	60	10	0	10	0	-	n
Om3	240-280	cs	5 YR2.5/1	5 YR3/4	w,mt	sst	6.2	4	0	0	30	30	30	0	10	0	-	n
Oh1	280-310	cs	10 YR2/1	10 YR2/2	m,mt	sst	6.2	6	0	0	10	10	80	0	0	0	-	n
Oh2	310-315	cs	10 YR2/1	10 YR2/1	ms	sst	-	7	0	0	10	0	90	0	0	0	-	n
IICg	315-335	-	5 Y5/1	-	ms	st	-	-	0	0	0	0	0	0	0	100	-	n

Sample Location: 45 Terric Fibric Mesisol

Field Description

Horizon	Depth (cm)	Boundary	Colour-Natural	Colour-Pressed	Struc.	Cons.	pH (H_2O)	von Post	Composition (%) S	B	M	C	A	SED	F	MIN	Other	Roots
Om1	0-40	gs	10 YR2/1	10 YR3/2	w,fi	nst	5.9	2	0	0	0	30	40	0	30	0	-	a
Of1	40-100	cs	10 YR2/1	7.5 YR3/3	w,fi	nst	5.9	3	0	20	0	30	30	0	20	0	-	vf
Om2	100-125	as	10 YR2/1	10 YR2/1	w,fi	nst	5.9	4	0	10	0	20	40	0	30	0	-	n
IICg	125-150	-	5 Y5/1	-	ms	vst	-	-	0	0	0	0	0	0	0	100	-	n

Sample Location: 51 Typic Fibrisol

Field Description

Horizon	Depth (cm)	Boundary	Colour-Natural	Colour-Pressed	Struc.	Cons.	pH (H_2O)	von Post	Composition (%) S	B	M	C	A	SED	F	MIN	Other	Roots
Om1	0-20	gs	10 YR2/1	10 YR3/3	w,fi	sst	6.0	3	0	20	20	10	40	0	10	0	-	a
Of1	20-65	cs	5 YR2.5/2	5 YR4/6	m,fi	nst	5.9	3	0	30	10	30	20	0	10	0	-	p
Of2	65-120	cs	7.5 YR3/2	7.5 YR4/4	w,fi	nst	5.9	4	0	40	0	20	30	0	10	0	-	vf
Of3	120-175	cs	5 YR3/4	7.5 YR4/6	m,mt	nst	5.6	4	0	40	0	30	10	0	20	0	-	n
Of4	175-230	gs	10 YR2/2	10 YR3/4	w,l/mt	nst	6.2	4	0	20	0	40	30	0	10	0	sd	n
Om2	230-260	cs	10 YR2/2	10 YR3/4	w,mt	sst	6.2	4	0	0	30	20	40	0	10	0	-	n
Om3	260-280	gs	10 YR2/1	10 YR3/3	s,mt	sst	6.8	5	0	0	0	20	70	0	10	0	-	n
Oh	280-295	cs	10 YR2/1	10 YR2/2	m,mt	sst	-	7	0	0	0	10	80	0	10	0	-	n
IICg	295-300	-	7.5 YR2/0	-	ms	-	-	-	0	0	0	0	0	0	0	100	-	n

Sample Location: 52 Typic Fibrisol

Field Description

Horizon	Depth (cm)	Boundary	Colour-Natural	Colour-Pressed	Struc.	Cons.	pH (H_2O)	von Post	Composition (%) S	B	M	C	A	SED	F	MIN	Other	Roots
Of1	0-30	cs	7.5 YR3/2	10 YR5/6	m,fi	nst	5.6	2	10	40	0	30	10	0	10	0	-	p
Of2	30-95	as	7.5 YR3/2	7.5 YR3/4	w,fi	nst	5.6	3	0	40	0	20	30	0	10	0	-	f
Of3	95-160	cs	7.5 YR3/4	10 YR5/8	w,l/mt	nst	5.6	4	0	40	0	30	20	0	10	0	sd	n
Of4	160-195	cs	7.5 YR3/4	10 YR5/8	w,mt	nst	5.3	3	0	40	0	50	10	0	0	0	sd	n
Om1	195-220	gs	5 YR2.5/1	5 YR2/3	w,mt	sst	5.3	4	0	20	0	30	30	0	20	0	sd	n
Om2	220-248	cs	5 YR3/4	10 YR2/2	w,mt	sst	6.2	5	0	0	10	10	70	0	10	0	-	n
IIAhbg	248-253	cs	10 YR2/1	-	ms	st	-	-	0	0	0	0	20	0	0	80	-	n
IICg	253-260	-	5 G5/1	-	ms	st	-	-	0	0	0	0	0	0	0	100	-	n

Sample Location: 53 Typic Fibrisol

Field Description

Horizon	Depth (cm)	Boundary	Colour-Natural	Colour-Pressed	Struc.	Cons.	pH (H_2O)	von Post	Composition (%) S	B	M	C	A	SED	F	MIN	Other	Roots
Om1	0-25	cs	10 YR2/1	10 YR2/2	w,fi	sst	6.2	3	0	20	0	20	50	0	10	0	-	a
Of1	25-60	gs	7.5 YR3/2	7.5 YR3/4	w,fi	nst	5.9	3	0	40	20	0	20	0	20	0	-	p
Of2	60-140	as	10 YR2/2	10 YR3/4	w,l/fi	nst	5.9	4	0	30	0	20	30	0	20	0	sd	f
Of3	140-200	cs	7.5 YR3/2	7.6 YR3/4	m,mt	nst	6.2	4	0	50	0	20	10	0	20	0	sd	n
Of4	200-235	gs	5 YR2.5/2	7.5 YR3/4	w,mt	sst	6.5	4	0	30	0	10	50	0	10	0	sd	n
Om2	235-275	cs	10 YR2/1	10 YR2/2	w,mt	sst	6.5	5	0	20	0	20	50	0	10	0	sd	n
Om3	275-300	cs	10 YR2/1	10 YR2/2	w,mt	sst	-	6	0	0	10	10	80	0	0	0	-	n
IICg1	300-310	-	5 G5/1	-	ms	-	-	-	0	0	0	0	0	0	0	100	-	n

Sample Location: 54 Typic Fibrisol

Field Description

Horizon	Depth (cm)	Boundary	Colour-Natural	Colour-Pressed	Struc.	Cons.	pH (H_2O)	von Post	Composition (%) S	B	M	C	A	SED	F	MIN	Other	Roots
Of1	0-25	cs	7.5 YR2/0	7.5 YR3/4	w,fi	nst	5.6	3	0	20	10	20	30	0	20	0	-	a
Of2	25-75	gs	5 YR2.5/2	5 YR3/4	w,fi	nst	5.9	4	0	40	0	10	30	0	20	0	sd	f
Of3	75-115	as	5 YR2.5/2	7.5 YR3/4	w,fi	nst	5.6	4	0	20	0	20	40	0	20	0	-	n
Of4	115-180	gs	10 YR4/6	10 YR5/8	w,l/fi	nst	5.6	3	0	60	0	30	10	0	0	0	sd	n
Om	180-195	cs	5 YR2.5/2	5 YR3/4	m,mt	sst	5.9	5	0	0	20	20	60	0	0	0	sd	n
Oh	195-210	as	7.5 YR3/2	7.5 YR3/4	ms	sst	6.2	7	0	0	10	10	80	0	0	0	-	n
IICg	210-220	-	5 GY5/1	-	ms	st	-	-	0	0	0	0	0	0	0	100	-	n

Sample Location: 55 Terric Mesisol

Field Description

Horizon	Depth (cm)	Boundary	Colour-Natural	Colour-Pressed	Struc.	Cons.	pH (H_2O)	von Post	Composition (%) S	B	M	C	A	SED	F	MIN	Other	Roots
Of	0-20	cs	5 YR3/4	5 YR4/6	m,fi	nst	6.2	2	0	40	0	10	10	0	40	0	-	a
Om1	20-70	gs	7.5 YR2/0	7.5 YR3/2	w,fi	sst	6.2	4	0	0	20	0	70	0	10	0	-	f
Om2	70-95	gs	5 YR2.5/1	5 YR2.5/2	w,mt	sst	5.9	5	0	0	0	10	70	0	10	10	-	n
Om3	95-130	as	5 YR2.5/1	5 YR2.5/2	w,mt	sst	5.9	5	0	0	0	0	70	0	20	10	-	n
IICg	130-140	-	5 GY5/1	-	ms	st	-	-	0	0	0	0	0	0	0	100	-	n

Sample Location: 56 Terric Humic Mesisol

Field Description

Horizon	Depth (cm)	Boundary	Colour-Natural	Colour-Pressed	Struc.	Cons.	pH (H_2O)	von Post	Composition (%) S	B	N	C	A	SED	F	MIN	Other	Roots
Om	0-40	gs	10 YR2/1	10 YR2/2	w,fi	nst	5.7	3	0	0	0	30	40	0	30	0	-	a
Oh	40-55	cs	10 YR2/1	10 YR2/1	ms	sst	5.9	5	0	0	0	0	90	0	10	0	-	f
IICg1	55-65	cs	10 YR3/1	-	ms	vst	-	-	0	0	0	0	0	0	0	100	-	n
IICg2	65-85	-	5 Y4/1	-	ms	vst	-	-	0	0	0	0	0	0	0	100	mo	n

Sample Location: 61 Typic Fibrisol

Field Description

Horizon	Depth (cm)	Boundary	Colour-Natural	Colour-Pressed	Struc.	Cons.	pH (H_2O)	von Post	Composition (%) S	B	N	C	A	SED	F	MIN	Other	Roots
Om1	0-20	cs	7.5 YR2/0	7.5 YR2/0	w,fi	sst	6.2	4	0	30	0	20	40	0	10	0	sd	p
Of1	20-65	cs	5 YR2.5/2	5 YR3/4	w,fi	nst	5.9	4	0	30	0	20	30	0	20	0	-	f
Of2	65-90	cs	5 YR3/3	5 YR4/6	w,mt	nst	5.6	3	0	30	0	20	30	0	20	0	sd	n
Of3	90-125	gs	5 YR2.5/2	10 YR3/3	w,fi	nst	5.6	4	0	40	0	20	30	0	10	0	sd	n
Of4	125-180	cs	5 YR3/4	5 YR4/6	w,mt	nst	5.3	3	0	60	0	20	10	0	10	0	-	n
Om2	180-220	cs	10 YR2/1	10 YR2/2	m,mt	sst	6.2	4	0	30	0	10	60	0	0	0	-	n
IICg	220-230	-	5 GY5/1	-	ms	st	-	-	0	0	0	0	0	0	0	100	-	n

Sample Location: 62 Terric Fibrisol

Field Description

Horizon	Depth (cm)	Boundary	Colour-Natural	Colour-Pressed	Struc.	Cons.	pH (H_2O)	von Post	Composition (%) S	B	M	C	A	SED	F	MIN	Other	Roots
Of1	0-35	cs	10 YR2/1	10 YR2/2	w,fi	nst	6.2	3	0	40	0	20	20	0	20	0	-	f
Of2	35-65	cs	10 YR2/2	10 YR3/3	w,fi	sst	5.9	4	0	30	0	10	30	0	30	0	-	f
Om	65-80	cs	5 YR3/2	5 YR3/3	m,mt	sst	6.2	4	0	0	10	10	70	0	10	0	-	n
Oh	80-90	gs	10 YR2/1	10 YR2/2	ms	sst	-	7	0	0	10	0	80	0	10	0	-	n
IICg	90-100	-	5 GY5/1	-	ms	st	-	-	0	0	0	0	0	0	0	100	-	n

Sample Location: 63 Terric Humic Fibrisol

Field Description

Horizon	Depth (cm)	Boundary	Colour-Natural	Colour-Pressed	Struc.	Cons.	pH (H_2O)	von Post	Composition (%) S	B	M	C	A	SED	F	MIN	Other	Roots
Oml	0-20	gs	7.5 YR2/0	7.5 YR3/4	w,fi	sst	5.9	2	0	30	0	20	30	0	20	0	-	a
Of1	20-65	cs	5 YR2.5/2	5 YR3/4	w,fi	nst	5.6	4	0	30	0	20	30	0	20	0	-	p
Oh	65-80	cs	10 YR2/2	7.5 YR3/4	m,mt	sst	-	7	0	0	0	0	90	0	10	0	-	n
IICg	80-90	-	5 GY5/1	-	ms	st	-	-	0	0	0	0	0	0	0	100	wo	n

Appendix 7.2

Data

Legend

x,y	Cartesian coordinates for geographic location
dup	duplicate
dep	depth (m)
elev	elevation of piezometer cavity (m AMSL)
K	saturated hydraulic conductivity (cm s^{-1})
mcv	in-situ moisture content %(v/v)
mcm	in-situ moisture content %(m/m)
db	bulk density (Mg m^{-3})
dbo	ash-free bulk density (Mg m^{-3})
dp	particle density (Mg m^{-3})
por	porosity (%)
vdr	void ratio
urf	unrubbed fiber content (%)
rf	rubbed fiber content (%)
pi	pyrophosphate index
ash	ash content (%)
pH	pH($CaCl_2$)
tcarb	total carbon content (%)
tnit	total nitrogen content (%)
exch	exchangeable hydrogen (cmol(+)kg^{-1})
excca	exchangeable calcium (cmol(+)kg^{-1})
excmg	exchangeable magnesium (cmol(+)kg^{-1})
excal	exchangeable aluminum (cmol(+)kg^{-1})
excna	exchangeable sodium (cmol(+)kg^{-1})
exck	exchangeable potassium (cmol(+)kg^{-1})
cec	cation exchange capacity (cmol (1/2 Ba++)kg^{-1})
cn	carbon:nitrogen
moss	moss content %(v/v)
herb	herbaceous content %(v/v)
wood	wood content %(v/v)
forlt	forest litter content %(v/v)
urvol	volume less than 0.5 mm %(v/v)

x	y	dup	dep	elev	k	mcv	mcm	db	dbo	dp	por	vdr
1	1	1	.76	589.04	.00140	75.0	523.9	.143	.13	1.57	.91	9.98
1	1	2	.76	589.04	.00140	78.8	550.0	.143	.13	1.57	.91	9.98
1	2	1	.72	588.66	.00037	53.3	530.2	.112	.10	1.57	.93	13.02
1	2	2	.72	588.66	.00037	77.2	431.1	.179	.15	1.57	.89	7.77
1	3	1	.72	588.72	.00170	86.2	441.9	.195	.17	1.57	.88	7.05
1	3	2	.72	588.72	.00170	71.8	531.8	.135	.12	1.57	.91	10.63
1	4	1	1.04	588.38	.00100	83.6	656.3	.127	.12	1.57	.92	11.36
1	4	2	1.04	588.38	.00100	86.6	739.2	.117	.11	1.57	.93	12.42
1	4	1	1.96	587.45	.00074	92.7	728.1	.127	.12	1.50	.92	10.81
1	4	2	1.96	587.45	.00074	95.4	555.9	.172	.16	1.50	.89	7.72
1	4	1	2.86	586.56	.00180	89.4	588.0	.152	.13	1.56	.90	9.26
1	4	2	2.86	586.56	.00180	92.7	570.7	.162	.14	1.56	.90	8.63
1	5	1	1.04	588.30	.00140	82.6	652.4	.127	.12	1.57	.92	11.36
1	5	2	1.04	588.30	.00140	90.4	694.1	.130	.12	1.57	.92	11.08
1	5	1	1.96	587.38	.00110	91.9	641.6	.143	.13	1.50	.90	9.49
1	5	2	1.96	587.38	.00110	97.6	499.0	.195	.16	1.50	.87	6.69
1	5	1	2.86	586.48	.00170	94.8	661.2	.143	.13	1.56	.91	9.91
1	5	2	2.86	586.48	.00170	93.4	588.1	.127	.11	1.56	.92	11.28
1	6	1	1.02	588.20	.00080	90.9	730.7	.124	.12	1.57	.92	11.66
1	6	2	1.02	588.20	.00080	77.8	745.2	.104	.09	1.57	.93	14.10
1	6	1	2.00	587.23	.00084	89.9	655.2	.137	.13	1.50	.91	9.95
1	6	2	2.00	587.23	.00084	84.4	692.9	.122	.11	1.50	.92	11.30
2	1	1	1.04	587.94	.00140	81.9	638.2	.128	.12	1.57	.92	11.27
2	1	2	1.04	587.94	.00140	92.2	643.1	.143	.13	1.57	.91	9.98
2	2	1	1.04	587.96	.00230	88.4	626.6	.141	.13	1.57	.91	10.13
2	2	2	1.04	587.96	.00230	84.8	611.9	.139	.13	1.57	.91	10.29
2	3	1	1.04	587.94	.00430	91.2	779.0	.117	.11	1.57	.93	12.42
2	3	2	1.04	587.94	.00430	83.9	738.6	.114	.10	1.57	.93	12.77
2	4	1	1.04	587.90	.00110	75.5	639.0	.118	.11	1.57	.92	12.31
2	4	2	1.04	587.90	.00110	89.3	603.8	.148	.14	1.57	.91	9.61
2	4	1	1.96	586.98	.00086	87.1	697.6	.125	.12	1.50	.92	11.00
2	4	2	1.96	586.98	.00086	93.0	645.9	.144	.13	1.50	.90	9.42
2	5	1	1.02	587.84	.00260	93.6	576.2	.162	.15	1.57	.90	8.69
2	5	2	1.02	587.84	.00260	83.4	673.0	.124	.11	1.57	.92	11.66
2	5	1	1.96	586.90	.00230	88.0	750.6	.117	.11	1.50	.92	11.82
2	5	2	1.96	586.90	.00230	90.4	704.7	.128	.12	1.50	.91	10.72
2	5	1	2.86	586.02	.00085	84.8	672.7	.126	.11	1.56	.92	11.38
2	5	2	2.86	586.02	.00085	89.5	645.2	.139	.12	1.56	.91	10.22
2	6	1	1.04	587.68	.00058	80.9	618.7	.131	.12	1.57	.92	10.98
2	6	2	1.04	587.68	.00058	81.0	683.9	.118	.11	1.57	.92	12.31
2	6	1	2.00	586.74	.00110	86.4	799.2	.108	.10	1.50	.93	12.89
2	6	2	2.00	586.74	.00110	91.6	842.9	.109	.10	1.50	.93	12.76
2	6	1	2.88	585.84	.00031	88.5	566.5	.156	.14	1.56	.90	9.00
2	6	2	2.88	585.64	.00031	82.7	620.7	.133	.12	1.56	.91	10.73
3	1	1	1.04	587.86	.00097	81.8	702.2	.116	.11	1.57	.93	12.53
3	1	2	1.04	587.86	.00097	85.6	720.5	.120	.11	1.57	.92	12.08
3	1	1	1.96	586.94	.00270	82.4	903.3	.091	.09	1.50	.94	15.48
3	1	2	1.96	586.94	.00270	85.0	811.2	.105	.10	1.50	.93	13.29
3	1	1	2.86	586.04	.00020	91.2	597.1	.153	.14	1.56	.90	9.20
3	1	2	2.86	586.04	.00020	93.2	577.2	.161	.14	1.56	.90	8.69
3	2	1	1.04	587.73	.00630	84.0	652.0	.129	.12	1.57	.92	11.17
3	2	2	1.04	587.73	.00630	83.7	660.4	.127	.12	1.57	.92	11.36
3	2	1	1.96	586.80	.00280	83.4	732.4	.114	.11	1.50	.92	12.16
3	2	2	1.96	586.80	.00280	86.5	955.9	.090	.08	1.50	.94	15.67
3	3	1	1.04	587.52	.00096	87.0	710.7	.122	.11	1.57	.92	11.87
3	3	2	1.04	587.52	.00096	85.7	755.4	.113	.10	1.57	.93	12.89
3	3	1	1.94	586.60	.00190	90.6	639.5	.142	.13	1.50	.91	9.56
3	3	2	1.94	586.60	.00190	87.0	821.8	.106	.10	1.50	.93	13.15
3	4	1	1.04	587.46	.00051	85.2	675.9	.126	.12	1.57	.92	11.46
3	4	2	1.04	587.46	.00051	80.2	762.3	.105	.10	1.57	.93	13.95
3	4	1	1.96	586.56	.00100	88.7	732.7	.121	.11	1.50	.92	11.40
3	4	2	1.96	586.56	.00100	86.7	709.1	.122	.11	1.50	.92	11.30
3	5	1	1.04	587.48	.00053	75.1	644.7	.116	.11	1.57	.93	12.53
3	5	2	1.04	587.48	.00053	82.6	617.5	.134	.13	1.57	.91	10.72
3	5	1	1.96	586.56	.00100	84.6	672.7	.126	.12	1.50	.92	10.90
3	5	2	1.96	586.56	.00100	88.0	733.0	.120	.11	1.50	.92	11.50
3	5	1	2.86	585.66	.00037	91.3	558.6	.163	.14	1.56	.90	8.57
3	5	2	2.86	585.66	.00037	88.5	531.9	.166	.15	1.56	.89	8.40
3	6	1	1.04	587.26	.00240	86.8	685.7	.127	.12	1.57	.92	11.36
3	6	2	1.04	587.26	.00240	82.9	672.6	.123	.12	1.57	.92	11.76

x	y	dup	dep	elev	k	mcv	mcm	db	dbo	dp	por	vdr
3	6	1	1.96	586.32	.00033	85.4	783.6	.109	.10	1.50	.93	12.76
3	6	2	1.96	586.32	.00033	98.7	754.8	.131	.12	1.50	.91	10.45
3	6	1	2.86	585.42	.00013	94.3	592.3	.159	.14	1.56	.90	8.81
3	6	2	2.86	585.42	.00013	92.1	593.5	.155	.14	1.56	.90	9.06
4	1	1	1.04	587.44	.00350	87.6	613.1	.143	.13	1.57	.91	9.98
4	1	2	1.04	587.44	.00350	83.6	618.4	.135	.13	1.57	.91	10.63
4	1	1	1.98	586.50	.00094	85.8	725.0	.118	.11	1.50	.92	11.71
4	1	2	1.98	586.50	.00094	88.3	695.4	.127	.12	1.50	.92	10.81
4	2	1	1.04	587.40	.00330	89.2	693.8	.129	.12	1.57	.92	11.17
4	2	2	1.04	587.40	.00330	79.2	675.7	.117	.11	1.57	.93	12.42
4	2	1	1.96	586.48	.00110	87.0	691.6	.126	.12	1.50	.92	10.90
4	2	2	1.96	586.48	.00110	92.9	590.0	.158	.15	1.50	.89	8.49
4	3	1	1.04	587.32	.00120	86.9	668.0	.130	.12	1.57	.92	11.08
4	3	2	1.04	587.32	.00120	74.3	699.2	.106	.10	1.57	.93	13.81
4	3	1	1.96	586.40	.00260	90.9	778.0	.117	.11	1.50	.92	11.82
4	3	2	1.96	586.40	.00260	91.3	839.1	.109	.10	1.50	.93	12.76
4	4	1	1.04	587.14	.00054	83.1	637.0	.130	.12	1.57	.92	11.08
4	4	2	1.04	587.14	.00054	86.0	518.3	.166	.16	1.57	.89	8.46
4	4	1	1.96	586.22	.00100	92.9	687.6	.135	.13	1.50	.91	10.11
4	4	2	1.96	586.22	.00100	90.8	637.5	.142	.13	1.50	.91	9.56
5	1	1	1.04	587.24	.00099	81.2	616.0	.132	.12	1.57	.92	10.89
5	1	2	1.04	587.24	.00099	86.1	658.0	.131	.12	1.57	.92	10.98
5	1	1	1.96	586.32	.00110	88.2	677.0	.130	.12	1.50	.91	10.54
5	1	2	1.96	586.32	.00110	83.3	873.1	.095	.09	1.50	.94	14.79
5	2	1	1.04	587.26	.00140	85.4	647.1	.132	.12	1.57	.92	10.89
5	2	2	1.04	587.26	.00140	87.1	619.0	.141	.13	1.57	.91	10.13
5	2	1	1.98	586.34	.00130	91.3	742.3	.123	.12	1.50	.92	11.20
5	2	2	1.98	586.34	.00130	95.8	724.1	.132	.13	1.50	.91	10.36
5	3	1	1.04	587.08	.00150	83.9	677.1	.124	.12	1.57	.92	11.66
5	3	2	1.04	587.08	.00150	79.4	742.6	.107	.10	1.57	.93	13.67
5	3	1	1.98	586.14	.00081	85.4	710.5	.120	.11	1.50	.92	11.50
5	3	2	1.98	586.14	.00081	91.0	686.5	.132	.12	1.50	.91	10.36
5	4	1	1.06	586.42	.00049	76.1	582.6	.131	.12	1.57	.92	10.98
5	4	2	1.06	586.42	.00049	91.0	579.3	.157	.14	1.57	.90	9.00
5	5	1	.94	585.76	.00140	85.5	356.1	.232	.20	1.57	.85	5.77
5	5	2	.94	585.76	.00140	79.1	430.4	.184	.15	1.57	.88	7.53
6	1	1	1.04	586.94	.00210	85.9	616.8	.139	.13	1.57	.91	10.29
6	1	2	1.04	586.94	.00210	82.4	505.9	.163	.15	1.57	.90	8.63
6	2	1	.80	587.18	.00097	85.1	490.9	.173	.15	1.57	.89	8.08
6	2	2	.80	587.18	.00097	87.2	509.4	.171	.16	1.57	.89	8.18
6	3	1	.70	587.14	.00042	76.8	480.4	.160	.15	1.57	.90	8.81
6	3	2	.70	587.14	.00042	70.8	560.1	.126	.11	1.57	.92	11.46

x	y	dup	dep	urf	rf	pi	ash	ph	tcarb	tnit	exch	excca	excmg
1	1	1	.76	50.6	23.8	85.0	12.2	5.18	55.8	2.09	88.4	125.8	13.7
1	1	2	.76	58.9	28.7	90.0	9.1	5.15	54.2	2.24	86.6	124.8	13.9
1	2	1	.72	51.7	22.0	110.0	12.8	5.72	51.7	2.24	72.5	210.2	12.2
1	2	2	.72	53.3	20.7	150.0	15.3	5.68	51.4	1.72	81.0	221.5	11.8
1	3	1	.72	56.4	24.0	95.0	11.5	5.29	51.7	1.86	84.2	145.0	13.3
1	3	2	.72	52.4	17.9	13.0	13.0	5.26	51.4	1.92	95.0	157.2	13.1
1	4	1	1.04	39.2	20.9	8.5	5.4	5.14	55.9	2.11	75.9	140.0	17.4
1	4	2	1.04	67.5	27.8	9.5	8.7	5.08	54.4	1.95	85.5	144.7	17.4
1	4	1	1.96	78.2	43.7	8.0	6.4	5.16	55.4	1.79	84.7	123.4	15.2
1	4	2	1.96	65.3	37.9	8.0	5.5	5.19	54.8	1.90	76.0	120.0	15.6
1	4	1	2.86	64.7	30.3	15.5	15.2	5.12	51.3	1.94	89.3	146.6	16.3
1	4	2	2.86	67.6	33.5	16.0	15.0	5.15	51.7	1.77	49.6	136.4	15.8
1	5	1	1.04	65.3	30.5	6.0	7.0	5.28	54.0	2.26	75.2	146.6	16.8
1	5	2	1.04	59.3	27.9	7.7	9.9	5.20	53.8	2.50	81.1	157.7	17.6
1	5	1	1.96	68.4	39.6	8.5	7.3	5.33	55.2	1.81	85.6	132.8	13.6
1	5	2	1.96	59.2	34.3	8.0	16.6	5.38	54.8	2.21	43.3	123.8	14.2
1	5	1	2.86	69.5	31.3	23.5	11.4	5.14	53.2	2.24	94.0	143.6	14.7
1	5	2	2.86	72.9	31.2	19.0	10.8	5.05	53.6	1.91	104.0	146.1	14.3
1	6	1	1.02	55.2	48.3	7.5	5.5	5.19	54.7	2.19	75.7	137.2	17.0
1	6	2	1.02	63.5	35.3	6.5	9.1	5.18	55.3	2.30	77.7	140.9	17.6
1	6	1	2.00	59.2	33.9	12.5	6.3	5.25	54.2	2.22	78.6	102.2	11.2
1	6	2	2.00	62.7	37.5	9.3	5.8	5.19	54.8	2.08	84.2	107.5	11.4
2	1	1	1.04	59.4	28.6	30.0	9.9	5.45	53.3	2.06	66.4	174.7	19.2
2	1	2	1.04	56.2	33.0	26.5	12.0	5.36	53.7	1.70	75.0	165.0	18.4
2	2	1	1.04	58.3	33.3	22.5	7.9	5.30	55.3	1.79	82.9	162.1	14.0
2	2	2	1.04	72.3	31.6	22.7	9.0	5.26	54.4	1.54	85.0	167.3	14.8
2	3	1	1.04	60.6	30.0	13.5	7.9	5.16	54.9	1.89	79.6	123.0	16.3
2	3	2	1.04	66.1	26.6	15.0	8.5	5.10	54.6	1.92	85.2	138.4	17.6
2	4	1	1.04	58.1	24.2	5.5	7.8	5.12	54.6	2.44	80.9	129.1	15.3
2	4	2	1.04	60.6	33.1	6.5	6.5	5.13	56.9	2.32	75.7	161.1	14.3
2	4	1	1.96	65.1	38.9	11.0	7.3	5.08	53.7	2.10	89.7	132.8	13.6
2	4	2	1.96	62.1	31.0	10.2	7.4	5.10	55.3	1.94	79.3	110.7	11.8
2	5	1	1.02	61.0	26.4	6.0	7.0	5.18	56.7	1.99	28.4	137.4	16.7
2	5	2	1.02	57.8	25.8	7.0	7.4	5.23	55.6	2.10	82.6	139.8	17.0
2	5	1	1.96	64.3	32.9	7.5	7.0	5.17	56.3	2.12	76.4	107.1	13.8
2	5	2	1.96	72.5	40.5	7.5	6.0	5.11	56.6	2.04	80.6	111.3	13.8
2	5	1	2.86	62.3	47.1	11.0	9.1	5.15	55.1	2.38	82.0	109.6	14.0
2	5	2	2.86	62.8	22.8	17.3	10.4	5.20	55.9	2.43	86.1	113.2	14.6
2	6	1	1.04	58.3	26.1	7.0	7.4	5.27	53.9	2.31	75.3	133.6	16.5
2	6	2	1.04	59.5	28.5	8.5	7.6	5.29	55.7	2.32	73.8	143.8	16.5
2	6	1	2.00	63.5	38.7	6.0	6.2	5.46	53.8	2.16	70.0	103.7	13.7
2	6	2	2.00	73.5	41.3	6.5	6.5	5.33	54.3	2.11	69.7	99.8	13.2
2	6	1	2.88	55.9	27.8	22.0	11.2	5.22	53.7	2.10	89.8	144.0	15.0
2	6	2	2.88	51.6	20.0	20.0	10.3	5.19	54.3	2.53	80.8	137.6	15.3
3	1	1	1.04	61.5	30.2	10.0	8.0	5.45	54.8	1.99	73.9	159.1	14.7
3	1	2	1.04	60.0	23.8	10.5	8.6	5.40	54.5	2.07	69.9	169.0	15.7
3	1	1	1.96	53.5	29.8	11.0	5.6	5.48	55.7	2.01	69.1	117.1	11.9
3	1	2	1.96	89.9	53.4	6.5	5.3	5.50	56.0	1.96	64.9	118.7	11.8
3	1	1	2.86	53.2	22.9	22.0	10.2	5.53	55.4	2.38	75.8	162.6	15.0
3	1	2	2.86	45.0	17.6	18.5	10.1	5.51	52.7	2.44	72.7	165.5	15.0
3	2	1	1.04	57.4	21.4	15.0	8.4	5.48	53.3	2.19	66.7	118.2	13.5
3	2	2	1.04	57.3	25.4	17.0	9.0	5.43	55.3	2.22	70.9	165.0	13.5
3	2	1	1.96	70.2	38.1	12.0	6.8	5.19	53.8	1.57	81.6	133.9	10.0
3	2	2	1.96	78.3	45.3	12.0	8.1	5.17	53.2	1.37	85.8	129.0	9.6
3	3	1	1.04	59.0	30.3	8.0	7.3	5.27	54.5	2.34	76.1	140.4	16.0
3	3	2	1.04	63.2	27.8	9.5	7.6	5.33	53.7	2.03	76.9	132.7	15.2
3	3	1	1.94	63.9	29.6	14.0	8.5	5.20	54.3	2.03	86.9	134.2	15.9
3	3	2	1.94	73.3	27.4	12.0	8.6	5.16	54.5	2.05	91.7	118.4	15.9
3	4	1	1.04	54.3	27.2	10.5	8.5	5.17	53.9	1.99	82.2	140.5	14.6
3	4	2	1.04	60.2	31.7	6.0	6.3	5.19	54.2	2.14	75.0	124.8	14.4
3	4	1	1.96	62.2	34.4	11.0	6.0	5.20	55.5	2.27	28.7	102.7	9.7
3	4	2	1.96	50.7	21.5	15.0	7.8	5.20	53.4	2.24	91.4	106.8	9.7
3	5	1	1.04	53.8	26.4	6.0	6.7	5.10	55.3	2.11	78.8	126.3	15.3
3	5	2	1.04	55.3	29.6	5.5	6.0	5.15	55.9	2.32	77.7	120.8	14.8
3	5	1	1.96	65.1	37.4	8.0	7.4	5.13	55.2	1.81	76.1	108.2	12.9
3	5	2	1.96	53.2	38.4	7.0	5.9	5.15	54.5	2.03	75.5	103.6	12.6
3	5	1	2.86	63.8	30.0	22.0	11.6	5.24	52.8	2.16	81.5	161.6	15.0
3	5	2	2.86	56.6	30.8	15.5	9.8	5.23	54.2	2.31	83.4	133.7	13.4
3	6	1	1.04	54.2	31.1	5.0	7.6	5.15	54.7	2.33	66.2	119.7	15.4
3	6	2	1.04	58.6	31.8	5.0	6.4	5.15	55.3	2.34	71.9	124.0	15.7

x	y	dup	dep	urf	rf	p1	ash	ph	tcarb	tnit	exch	excca	excmg
3	6	1	1.96	63.0	34.5	7.5	6.3	5.18	53.6	2.18	67.2	104.6	12.2
3	6	2	1.96	60.1	34.4	8.0	5.8	5.17	54.5	2.15	69.3	98.9	11.5
3	6	1	2.86	47.0	21.6	18.2	9.0	5.32	54.6	2.61	27.4	129.6	11.1
3	6	2	2.86	48.0	22.7	20.0	9.6	5.31	52.9	2.60	71.3	133.5	10.5
4	1	1	1.04	53.7	25.3	15.0	8.1	5.23	54.5	2.22	42.6	140.8	19.0
4	1	2	1.04	58.4	28.7	11.0	7.3	5.25	53.7	2.12	70.9	137.5	18.2
4	1	1	1.98	63.3	31.6	10.0	6.4	5.45	54.3	2.57	68.4	111.1	13.8
4	1	2	1.98	64.4	33.5	7.5	6.6	5.37	53.2	2.18	68.8	115.6	14.2
4	2	1	1.04	53.0	19.6	11.0	9.8	5.14	55.8	2.17	81.4	146.0	15.2
4	2	2	1.04	56.9	25.3	10.0	9.0	5.13	53.6	2.61	76.9	134.6	13.9
4	2	1	1.96	64.4	30.0	9.0	5.9	5.19	55.1	2.45	73.2	94.9	9.1
4	2	2	1.96	58.0	30.2	9.0	5.3	5.16	55.2	2.12	76.4	104.7	9.5
4	3	1	1.04	51.5	28.1	7.0	6.7	5.10	54.2	2.00	81.4	124.5	17.1
4	3	2	1.04	60.8	30.2	8.0	6.2	5.11	55.5	1.14	77.4	127.6	17.6
4	3	1	1.96	79.5	38.0	9.0	6.6	4.95	53.7	1.36	92.6	113.6	15.6
4	3	2	1.96	83.4	36.9	10.0	6.1	4.96	53.8	1.46	82.2	115.3	16.2
4	4	1	1.04	55.0	29.6	9.0	7.0	5.11	54.5	2.03	84.0	136.6	17.3
4	4	2	1.04	66.5	37.4	6.0	5.4	5.22	55.2	2.17	73.2	109.2	14.6
4	4	1	1.96	64.8	32.5	7.5	6.7	5.13	55.6	2.09	79.6	105.4	14.1
4	4	2	1.96	66.5	46.7	7.5	6.3	5.21	53.6	2.26	66.3	101.6	14.5
5	1	1	1.04	48.6	20.6	7.0	8.4	5.24	54.6	2.38	78.1	136.8	15.2
5	1	2	1.04	58.4	32.8	8.0	7.1	5.36	51.6	2.31	66.1	124.1	14.7
5	1	1	1.96	65.5	36.8	6.5	5.6	5.30	55.6	2.20	68.2	113.7	15.0
5	1	2	1.96	66.1	48.6	8.0	5.4	5.23	54.6	2.02	78.4	115.1	14.3
5	2	1	1.04	53.1	25.8	8.0	7.2	5.11	57.1	2.38	78.0	131.5	18.2
5	2	2	1.04	50.9	29.4	10.0	8.3	5.11	55.6	2.54	81.1	126.7	17.2
5	2	1	1.98	68.5	44.0	7.0	6.1	5.22	54.5	2.02	77.0	112.9	12.9
5	2	2	1.98	65.1	42.1	9.0	5.3	5.22	55.0	1.97	78.8	113.1	12.9
5	3	1	1.04	54.6	31.0	7.0	6.8	5.38	55.2	2.42	74.2	128.4	15.1
5	3	2	1.04	55.1	27.7	7.5	6.5	5.38	55.3	2.36	68.1	131.2	14.8
5	3	1	1.98	58.9	36.7	8.0	6.1	5.36	54.8	1.96	78.3	100.0	14.3
5	3	2	1.98	64.6	36.1	8.0	6.5	5.25	55.0	2.07	73.0	106.9	15.0
5	4	1	1.06	57.1	31.7	11.5	8.1	5.20	54.2	2.13	83.4	121.9	15.1
5	4	2	1.06	61.2	32.4	9.5	8.1	5.14	54.3	2.21	78.6	131.6	14.3
5	5	1	.94	56.0	20.1	70.0	12.8	4.97	52.0	1.87	119.5	123.3	10.2
5	5	2	.94	53.7	26.1	50.0	16.7	4.99	47.8	1.66	117.7	112.9	9.3
6	1	1	1.04	49.2	26.0	11.0	7.0	5.18	53.6	2.52	77.2	115.8	13.5
6	1	2	1.04	52.1	29.7	9.0	7.6	5.21	54.4	2.50	76.0	117.6	13.1
6	2	1	.80	61.5	17.0	65.0	11.4	5.46	52.4	2.30	91.9	114.8	9.9
6	2	2	.80	51.9	23.2	30.0	8.4	5.41	52.7	2.68	86.6	119.4	9.7
6	3	1	.70	41.3	21.3	80.0	9.2	4.94	53.9	2.28	102.5	130.2	12.0
6	3	2	.70	40.2	17.2	60.0	10.8	5.01	52.6	2.05	29.8	115.6	11.8

x	y	dup	dep	excal	excna	exck	cec	cn	moss	herb	wood	forlt	urvol
1	1	1	.76	2.20	.27	.070	230.4	23.44	.1	9.7	14.6	.5	75.1
1	1	2	.76	2.70	.42	.070	228.4	21.99	.4	11.3	12.1	.8	75.4
1	2	1	.72	2.40	.48	.071	297.8	20.13	1.2	16.6	15.4	.2	66.6
1	2	2	.72	2.60	.36	.071	317.3	25.31	2.8	15.5	7.3	.2	74.3
1	3	1	.72	2.20	.49	.072	245.3	24.60	.8	18.8	18.4	3.5	58.6
1	3	2	.72	2.20	.31	.073	267.9	23.29	.8	2.7	5.6	1.1	89.9
1	4	1	1.04	1.10	.24	.070	234.7	25.06	1.8	29.3	14.0	9.7	45.2
1	4	2	1.04	1.00	.28	.066	248.9	25.47	2.5	26.6	14.4	7.6	48.9
1	4	1	1.96	.74	.29	.068	224.4	28.97	13.3	17.0	9.2	8.5	52.0
1	4	2	1.96	1.00	.41	.069	213.1	27.26	12.5	25.5	6.5	7.9	47.6
1	4	1	2.86	1.20	.59	.070	254.1	22.42	.6	5.7	29.4	12.9	51.5
1	4	2	2.86	1.20	.55	.073	203.6	24.83	.2	9.7	24.4	9.0	56.7
1	5	1	1.04	1.30	.50	.073	240.5	22.22	6.5	12.7	10.0	6.4	64.5
1	5	2	1.04	1.30	.44	.074	258.2	19.39	1.1	14.2	15.0	7.5	62.2
1	5	1	1.96	1.30	.40	.068	233.8	28.27	1.6	14.4	10.4	4.3	69.3
1	5	2	1.96	1.40	.43	.072	183.2	20.68	3.2	25.0	4.7	6.0	61.0
1	5	1	2.86	1.60	.62	.074	254.6	21.04	.7	11.6	12.6	3.5	71.6
1	5	2	2.86	1.50	.69	.068	266.6	25.03	.6	5.2	11.2	2.7	80.2
1	6	1	1.02	1.20	.64	.069	231.8	23.60	1.5	10.7	11.4	4.0	72.4
1	6	2	1.02	1.20	.66	.070	238.1	21.86	1.6	13.5	10.8	4.7	69.4
1	6	1	2.00	2.30	.67	.071	195.0	22.88	6.6	35.7	10.4	1.3	46.1
1	6	2	2.00	1.60	.52	.068	205.3	24.82	3.5	18.4	10.0	1.7	66.4
2	1	1	1.04	1.70	.25	.073	262.3	23.31	3.3	3.1	13.3	3.8	76.5
2	1	2	1.04	1.40	.24	.070	260.1	27.80	2.9	13.2	11.8	6.3	65.9
2	2	1	1.04	1.40	.31	.074	260.8	28.45	2.3	15.5	14.5	3.0	64.6
2	2	2	1.04	1.60	.55	.069	269.3	32.15	5.3	16.6	10.7	4.1	63.3
2	3	1	1.04	1.00	.32	.067	220.3	26.75	1.8	6.7	11.0	4.2	76.3
2	3	2	1.04	1.40	.42	.071	195.0	26.02	1.5	9.9	13.9	6.8	67.9
2	4	1	1.04	.91	.36	.070	226.6	20.63	4.2	13.0	9.5	5.2	68.0
2	4	2	1.04	.86	.30	.072	252.3	22.93	3.1	7.1	2.4	1.4	86.0
2	4	1	1.96	1.40	.42	.070	238.0	23.70	6.7	20.1	6.9	2.7	63.6
2	4	2	1.96	1.30	.40	.072	203.6	26.40	8.9	14.3	3.9	1.6	71.3
2	5	1	1.02	1.10	.42	.072	184.1	26.50	2.3	9.6	19.8	6.9	61.4
2	5	2	1.02	1.20	.42	.070	241.1	24.52	1.3	12.1	9.0	4.8	72.7
2	5	1	1.96	.94	.37	.072	198.7	24.70	7.4	7.5	1.7	1.4	81.9
2	5	2	1.96	.94	.55	.072	207.3	26.08	24.4	21.3	3.9	3.6	46.8
2	5	1	2.86	.92	.66	.071	207.2	21.22	1.0	25.9	6.1	6.5	60.5
2	5	2	2.86	1.20	.71	.070	215.9	20.61	.8	21.5	5.7	4.5	67.5
2	6	1	1.04	1.20	.55	.072	227.2	21.61	1.2	25.0	15.1	15.4	43.3
2	6	2	1.04	1.10	.43	.072	235.7	22.18	1.4	27.2	7.6	8.8	55.0
2	6	1	2.00	1.20	.66	.071	189.3	23.36	21.0	17.4	1.5	.7	59.4
2	6	2	2.00	.92	.66	.071	184.4	24.06	28.5	22.6	2.4	4.0	42.5
2	6	1	2.88	1.20	.48	.070	250.6	22.71	.6	13.2	25.1	5.3	56.0
2	6	2	2.88	1.40	.61	.072	235.8	19.25	.1	10.0	5.9	2.4	81.6
3	1	1	1.04	1.00	.35	.069	249.1	25.33	3.2	9.5	11.4	9.2	66.6
3	1	2	1.04	1.40	.49	.072	256.6	24.06	4.2	13.5	12.5	5.3	64.6
3	1	1	1.96	1.10	.61	.071	200.5	26.16	17.5	29.2	5.3	2.7	45.3
3	1	2	1.96	.93	.54	.072	196.9	27.06	26.7	35.2	7.6	4.0	26.4
3	1	1	2.86	1.60	.62	.072	255.7	20.90	5.5	30.0	6.4	2.7	55.4
3	1	2	2.86	1.70	.74	.072	255.7	19.42	2.0	19.3	5.1	3.2	70.5
3	2	1	1.04	1.40	.24	.071	200.1	22.29	.7	11.3	13.6	6.7	67.7
3	2	2	1.04	1.40	.12	.070	215.9	22.67	.9	12.2	15.4	3.9	67.6
3	2	1	1.96	1.20	.36	.072	227.1	31.94	32.0	28.5	11.1	1.9	26.5
3	2	2	1.96	1.30	.31	.073	226.1	35.69	13.1	13.8	7.9	1.7	63.5
3	3	1	1.04	1.40	.54	.070	234.5	21.59	3.7	10.9	11.0	4.8	69.6
3	3	2	1.04	.96	.38	.074	226.2	24.44	1.8	5.9	12.6	2.7	77.0
3	3	1	1.94	1.10	.30	.071	219.8	24.48	14.6	23.6	8.8	6.6	46.4
3	3	2	1.94	1.30	.85	.068	228.2	24.30	15.7	17.6	7.7	5.4	53.7
3	4	1	1.04	1.40	.43	.072	239.2	24.78	3.0	23.2	10.3	4.9	58.6
3	4	2	1.04	1.10	.44	.110	215.8	23.73	11.1	16.0	7.5	6.6	58.7
3	4	1	1.96	2.30	.30	.072	143.8	22.98	26.3	44.7	6.8	1.2	21.0
3	4	2	1.96	2.80	.36	.072	211.1	21.98	10.4	28.3	6.5	2.7	52.1
3	5	1	1.04	.95	.49	.073	221.9	24.45	2.4	15.0	14.8	3.2	64.6
3	5	2	1.04	.87	.34	.067	214.6	22.65	3.7	20.8	8.2	5.4	62.0
3	5	1	1.96	.92	.42	.070	198.6	28.24	12.7	12.5	3.3	4.0	67.4
3	5	2	1.96	.88	.57	.067	193.2	25.26	4.8	6.6	1.7	2.2	84.6
3	5	1	2.86	1.60	.41	.069	260.2	21.61	.2	12.6	18.3	4.9	64.0
3	5	2	2.86	1.40	.39	.070	232.4	21.16	.7	12.6	12.9	4.6	69.2
3	6	1	1.04	1.10	.48	.071	203.0	21.69	1.3	15.3	12.8	7.3	63.3
3	6	2	1.04	1.00	.46	.071	213.1	22.12	1.9	13.0	16.7	4.4	64.0

x	y	dup	dep	excal	excna	exck	cec	cn	moss	herb	wood	forlt	urvol
3	6	1	1.96	1.10	.36	.066	185.5	23.04	7.1	14.7	1.5	.1	76.6
3	6	2	1.96	.81	.44	.075	181.0	23.88	20.9	21.0	1.7	1.6	54.9
3	6	1	2.86	1.20	.36	.071	169.7	19.04	.2	20.6	2.3	1.4	75.6
3	6	2	2.86	.92	.18	.071	216.5	18.39	.2	24.2	6.8	.9	67.9
4	1	1	1.04	1.40	.43	.072	204.3	22.56	.8	18.7	9.9	2.8	67.8
4	1	2	1.04	1.20	.48	.070	228.4	23.48	.3	10.0	2.9	.8	86.0
4	1	1	1.98	1.10	.61	.072	195.1	19.78	24.5	23.1	1.8	.7	50.0
4	1	2	1.98	1.10	.61	.072	200.4	22.79	10.3	13.2	7.4	1.2	67.9
4	2	1	1.04	1.20	.36	.071	244.2	23.19	8.9	26.9	9.7	2.0	52.5
4	2	2	1.04	1.40	.43	.072	227.3	18.69	4.4	25.9	12.4	4.7	52.6
4	2	1	1.96	.91	.36	.070	178.5	21.16	18.1	17.2	.6	.3	63.8
4	2	2	1.96	.90	.29	.069	191.8	24.66	14.6	14.7	5.0	.9	64.9
4	3	1	1.04	1.10	.42	.070	224.6	25.28	3.9	10.9	8.2	3.6	73.4
4	3	2	1.04	1.00	.40	.068	224.1	45.67	4.1	11.6	9.8	4.3	70.3
4	3	1	1.96	.90	.53	.069	223.3	36.88	14.9	27.3	3.8	1.7	52.3
4	3	2	1.96	.94	.55	.072	215.3	34.60	13.8	13.5	5.8	1.3	65.6
4	4	1	1.04	.76	.18	.070	238.9	24.97	.1	21.4	13.5	1.4	63.6
4	4	2	1.04	.76	.30	.070	198.1	24.06	8.7	26.4	4.0	5.0	55.9
4	4	1	1.96	.76	.47	.070	200.4	24.82	21.7	25.0	6.1	1.7	45.5
4	4	2	1.96	1.10	.67	.071	184.2	22.22	17.2	16.6	1.9	.2	64.1
5	1	1	1.04	1.00	.29	.068	231.4	21.01	2.6	16.5	11.6	2.6	66.7
5	1	2	1.04	1.10	.31	.073	206.4	20.75	10.0	11.1	5.8	1.4	71.7
5	1	1	1.96	1.20	.61	.072	198.8	23.86	26.1	14.5	3.6	1.7	54.1
5	1	2	1.96	.62	.24	.071	208.7	25.57	36.0	11.6	5.4	2.0	45.0
5	2	1	1.04	1.00	.41	.070	229.2	22.26	1.7	14.8	12.9	1.6	69.0
5	2	2	1.04	.98	.42	.070	226.5	20.07	1.6	17.1	11.9	1.7	67.6
5	2	1	1.98	.83	.60	.071	204.3	25.33	28.3	20.7	5.2	1.1	44.6
5	2	2	1.98	.90	.53	.069	206.3	26.44	30.0	17.9	3.7	2.8	45.6
5	3	1	1.04	1.10	.49	.072	219.4	26.26	2.7	15.1	9.9	1.4	70.8
5	3	2	1.04	1.20	.30	.070	215.7	21.91	2.0	20.2	13.6	2.2	62.0
5	3	1	1.98	.78	.68	.072	194.1	26.25	25.0	12.9	3.2	.7	58.1
5	3	2	1.98	1.10	.66	.071	196.7	24.84	20.2	14.0	3.0	1.1	61.7
5	4	1	1.06	2.20	.37	.072	223.0	23.38	8.6	14.8	6.5	2.3	67.8
5	4	2	1.06	1.60	.43	.072	226.6	22.58	10.8	19.3	12.0	2.4	55.5
5	5	1	.94	2.00	.30	.072	255.4	24.25	3.4	5.4	18.8	.4	72.0
5	5	2	.94	1.80	.19	.073	242.0	23.99	6.4	6.5	21.1	1.0	65.0
6	1	1	1.04	1.20	.46	.072	208.2	19.78	4.1	14.6	9.1	.2	72.0
6	1	2	1.04	1.30	.47	.069	208.5	20.11	7.9	22.3	7.9	.2	61.7
6	2	1	.80	2.80	.30	.071	219.8	20.19	1.2	12.5	12.9	1.0	72.5
6	2	2	.80	1.80	.54	.210	218.5	18.01	.8	13.4	8.5	1.4	75.9
6	3	1	.70	2.50	.37	.072	247.6	21.47	.1	10.0	8.0	.5	81.4
6	3	2	.70	3.80	.37	.072	161.4	22.89	.1	14.1	12.7	1.1	72.1